# Proceedings
# IREAPS Technical Symposium
## September 14-16-1982
## San Diego, California

## VOLUME I

INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

I R E A P S

# Report Documentation Page

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Institute for
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Productivity in
Shipbuilding

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## PREFACE

IREAPS is an independent not-for-profit membership corporation founded in April 1981 to direct the 9 year-old REAPS Program. The IREAPS Program is a U.S. shipbuilding industry/Maritime Administration cooperative effort whose goal is the improvement of shipbuilding productivity through the application of computer aids and production technology.

The Ninth Annual IREAPS Technical Symposium, held September 14-16, 1982 in San Diego, California, represents one element of the IREAPS Program which is designed to provide industry with the opportunity to review new developments in shipyard technology.

The Symposium this year highlighted all aspects of the National Shipbuilding Research Program (NSRP) in that presentations were made by all the panel chairmen of the SNAME Ship Production Committee.

The 1982 IREAPS Technical Symposium Proceedings contain most of the papers presented at the meeting. The agenda in Appendix A indicates topics and speakers; Appendix B is a list of symposium attendees. All current SPC-SNAME chairmen are identified in Appendix C.

Many thanks to all those who have contributed to the success of this year's Symposium.

Linda M. Bender

Linda M. Bender
General Chairman
1982 IREAPS Technical Symposium

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## KEYNOTE ADDRESS

# CONSIDERATIONS REGARDING IMPROVED PRODUCTIVITY BASED UPON EXPERIENCE OF SERIES PRODUCTION OF MERCHANT SHIPS

Cato F. Sverdrup
Managing Director
Burmeister and Wain Shipyard
Copenhagen, Denmark

Mr. Sverdrup holds a degree from Massachusettes Institute of Technology. He has 22 years of experience in Denmark, that covers all phases of shipbuilding.

## ABSTRACT

In 1960 B&W Shipyard commissioned new yard facilities introducing new building methods with large blocks (modules, sections) assembled in the building dock by gantry cranes. To ensure effective operation of such facilities, computer based sophisticated planning and control systems were developed. The anticipated improvement in production efficiency of the new system remained, however, for the first decade of operation, as it was with traditional shipbuilding. Upon thorough analysis of the situation the yard management was forced to acknowledge that the excessive complexity of systems applied had made the understanding of fundamental parameters for successful planning and control of new systems ambiguous.

Accepting that shipbuilding is only as complicated as one chooses to make it, the yard started to simplify all phases of the shipbuilding processes. Discarding complicated systems and for one off production, efforts were centered on series production of ships to improve productivity sampling whatever Japanese impulses were considered adaptable to the yard.

Over a two-year period the yard more than doubled the throughput while at the same time reducing man-hours per ship by close to 50%. Specializing in Panamax bulk carriers at peak efficiency, the yard launched one vessel from its building dock every 28 working days. Some basic considerations are covered as to how productivity can be achieved by relying more on common sense than on complicated computer systems.

# 1. INTRODUCTION

Except for government provision offering customer financing on OECD terms, Danish shipyards receive no subsidies and must compete in the open market against efficient Far Eastern yards with a low labour cost or against less efficient European yards, where pricing is governed more by the need of securing employment or hard Western currency than by sound business considerations.

In meeting this competition the policy of Burmeister & Wain Shipyard in recent years has been to concentrate on series production, even at sales prices lower than may be obtained for more specialized tailored "one off" products. The yard has found advantages of series production sufficient to compensate for lower price per unit, providing market conditions justify expectations of sales.

In the sixties Burmeister & Wain had a somewhat limited success in obtaining orders for larger series production, except for 25 fish factory ships (Figure 1) built in batches in between other production.

In the seventies the yard, however, succeeded in obtaining orders for 23 bulk carriers of each 52,000 dwt (BC 50), followed by 14 Panamax bulk carriers of 60,000 dwt (BC60) built in succession in the period between 1975 and 1977. Figure 1 shows the series as obtained in the period 1955-77 which on a percentage basis compared favourably even in accordance with Japanese records Figure 2.

Burmeister & Wain Shipyard is presently engaged in the production of further 18 of Panamax size (BC60E2), similar to the previous series except for improved fuel efficiency.

*

In the fifties Burmeister & Wain Shipyard conceived and implemented the system of gantry crane assembly of large steel blocks in a building dock at a considerable cost. Productivity, however, did not improve for major reasons of product mix and newly adopted systems that made recognition of rudimentary factors of performance somewhat ambiguous.

After a decade where yard productivity barely surpassed past performance at old berths, losses accumulated as competition grew harder.

Eventually, as yard management was forced to acknowledge that the previous approach was not applicable, a policy was adopted based upon series production and a simplified approach to planning with particular priority to the objective of increasing throughput maintaining labour force at approximate constant level.

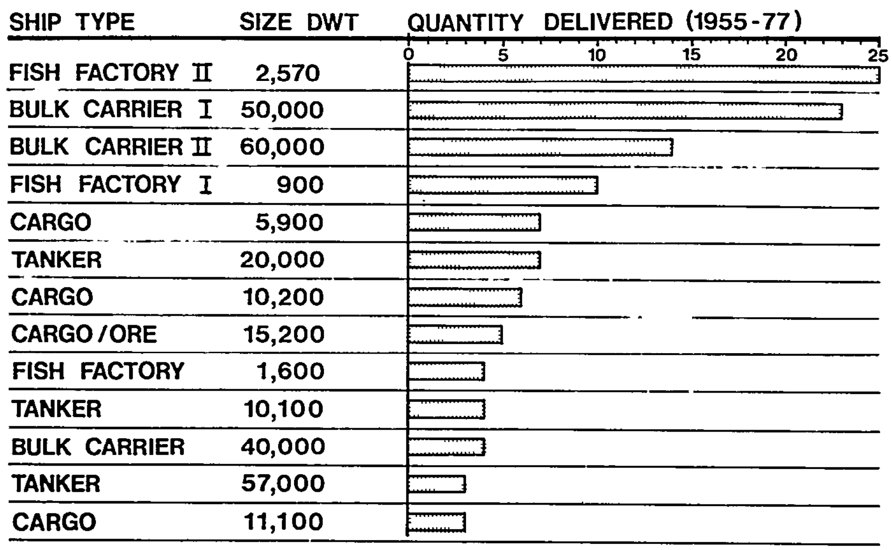



FIG. 1 SERIES PRODUCED 1955-77

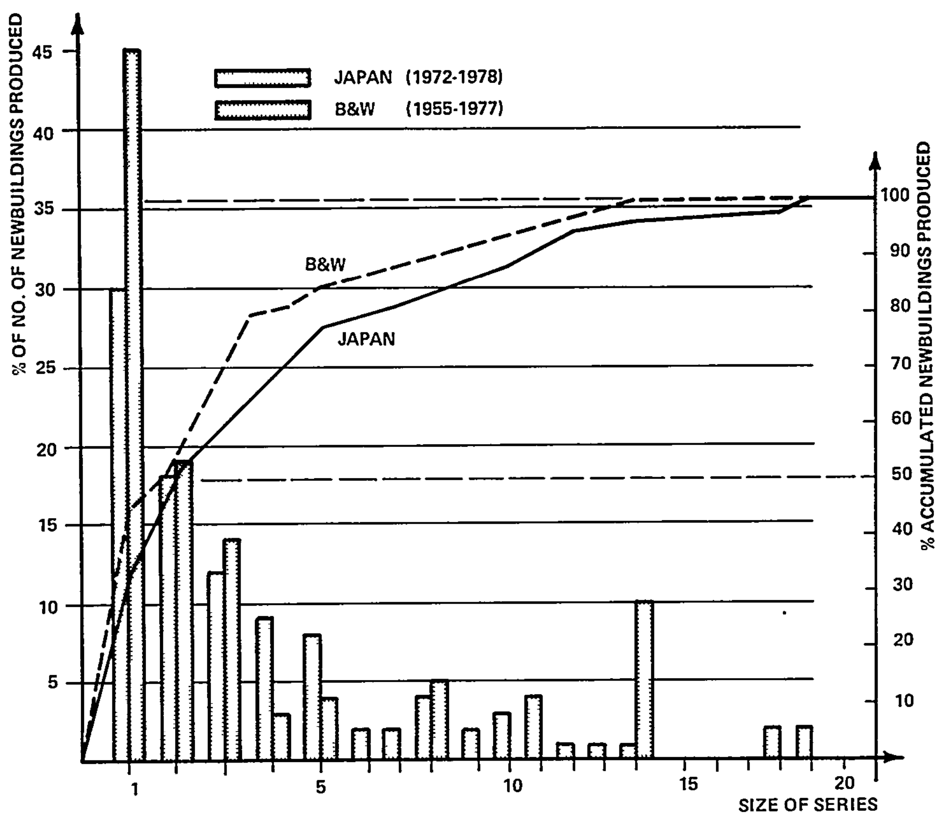



FIG. 2 COMPARISON OF SERIES PRODUCTION

In the years 1972 to 1976 the production of bulk carriers rose from 3.5 to 7.5 per year equivalent to an increase in steel output from 30,000 to 78,000 tons per year (Figure 3).

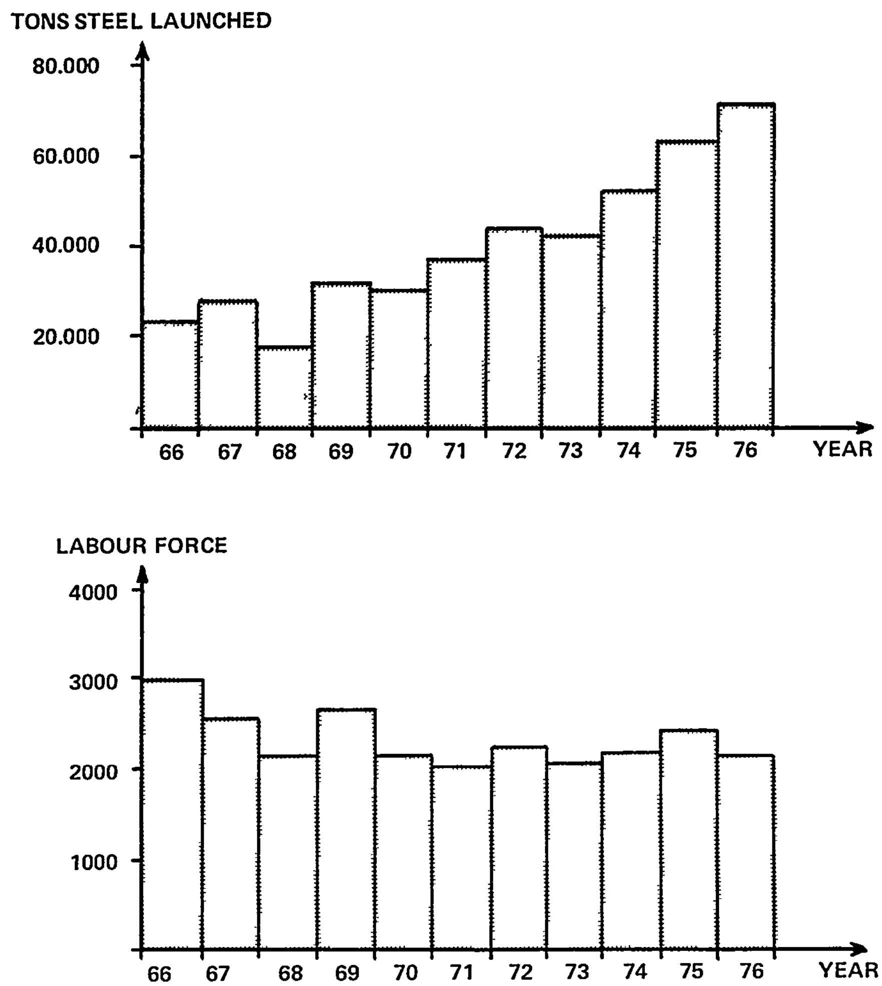



FIG. 3 **LABOUR FORCE AND TONS STEEL LAUNCHED AT THE YARD IN PERIOD 1966 TO 1977**

The topic of today is to give some factors as found essential in achieving this improvement.

## 2. PRODUCTIVITY

By definition productivity for a specified ship complexity can only be improved by increasing output or by reducing manhours.

Reduction of manhours thus becomes an objective only obtainable by reduction in work force, if production rate is to be maintained. It is somewhat astonishing in declining markets to register arguments from yards requesting government grants for investments and support of operating costs for the contradictory purpose of improving efficiency while maintaining employment.

Improvement of productivity may be obtained through parameters summarized as follows:

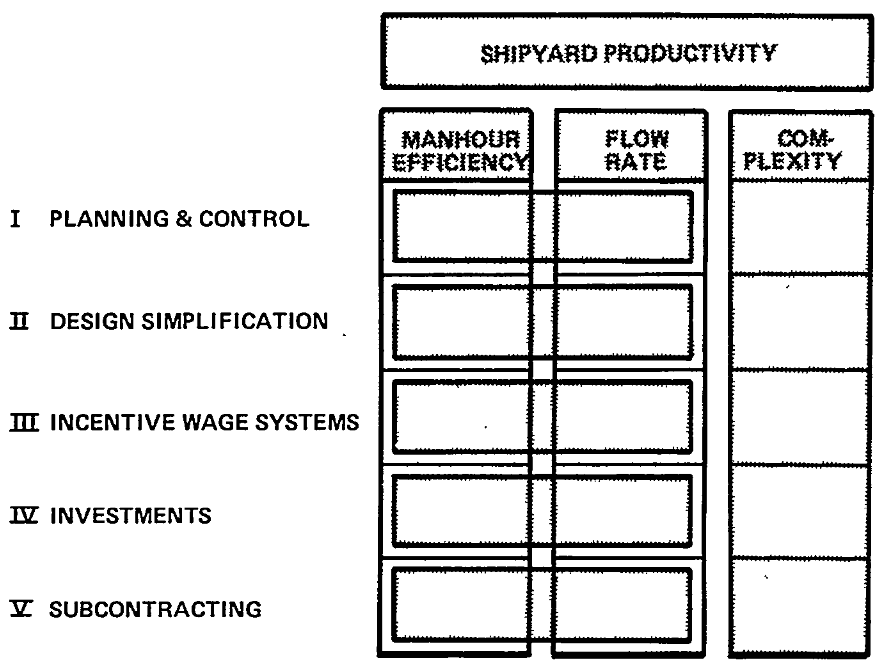
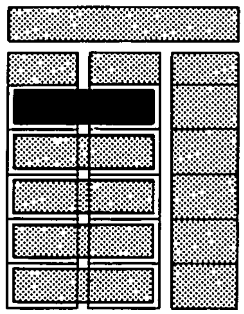



FIG. 4

The complexity of work content can be difficult to define, and is hopefully reflected in a contractual price allowance for increased value.

As the topic of consideration is productivity in series production, complexity becomes fixed and factors of productivity can better be recognized when evaluating records of past performance.

## 3. PLANNING AND CONTROL



Reduction in manhours is by nature the objective of every shipyard management. For series production this reduction is expected as repetitive effect of experience takes place.

Figure 5 shows the outfitting manhours on the comparatively complex fish factory ships. These ships were built in between 29 other cargo ships, tankers and bulk carriers ranging in size from 10 to 80,000 dwt. The series effect on these complicated ships is conspicuously large due to complexity of work content, insufficient planning and preparation and effects of batch production until the point where employees are so familiarized with the product that efficiency is maintained even with mixed production.

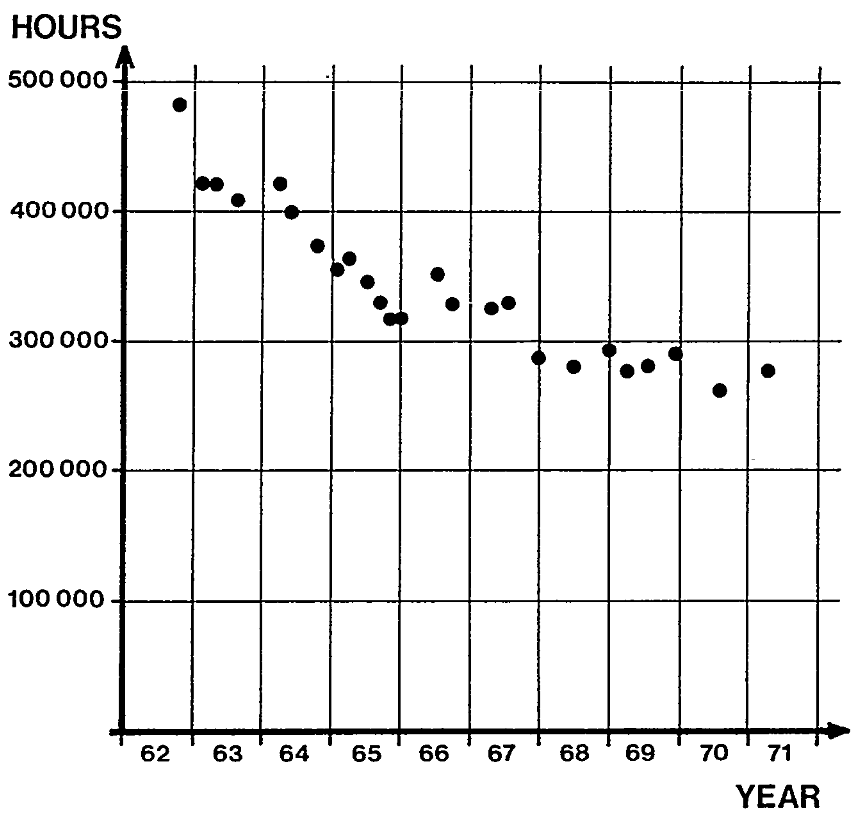



FIG. 5 OUTFITTING HOURS FOR FISH FACTORY SHIPS

Manhours for the bulk carriers are shown in Figure 6. The first four vessels built almost in succession (group A) showed remarkable improvement in efficiency, subsequent sisterships (group B), built in between other production, showed considerable increase in manhours. Evaluation of performance in building these ships indicated allocation of labour had little effect on steel output, as registered manhours were dependent only on number of people employed (Figure 7). Quite evidently, obstructions existed that could not be overcome by manpower alone.

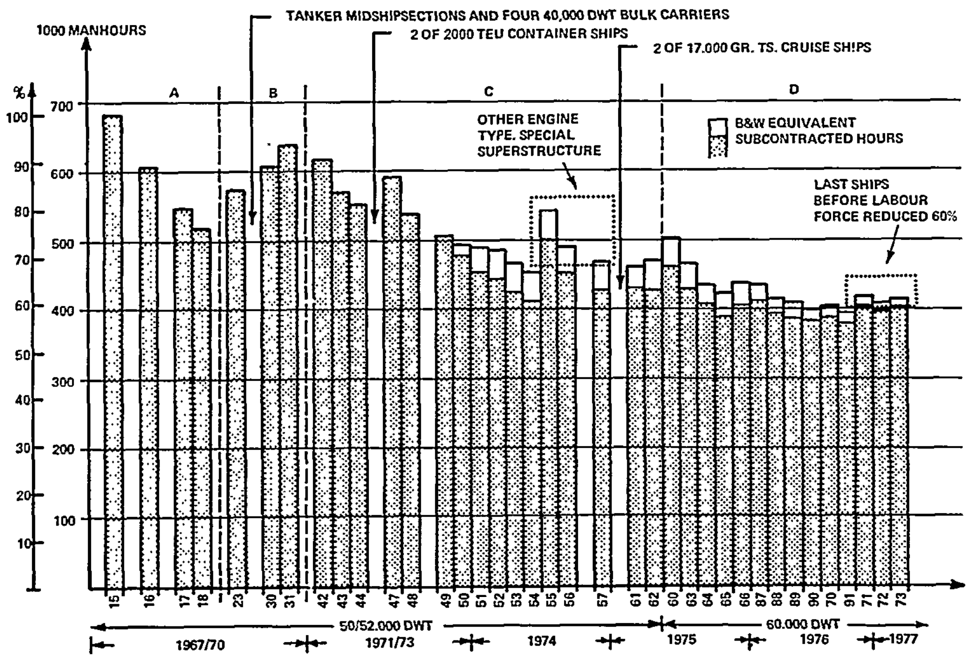



**FIG. 6 DIRECT MANHOURS FOR BULK CARRIERS BUILT IN SERIES AT B&W SHIPYARD IN THE PERIOD 1967 TO 1977**

In analyzing this problem in steel production a flow chart was made registering the movement of more than 48,000 pieces of steel (Figure 8). Production targets were thereupon subdivided workshopwise into items produced within the required period of time. Planning and follow up was based upon parameters best correlated to work content, (schematically shown in Figure 9), and previously registered manhours and the systems based thereupon were more or less disregarded.

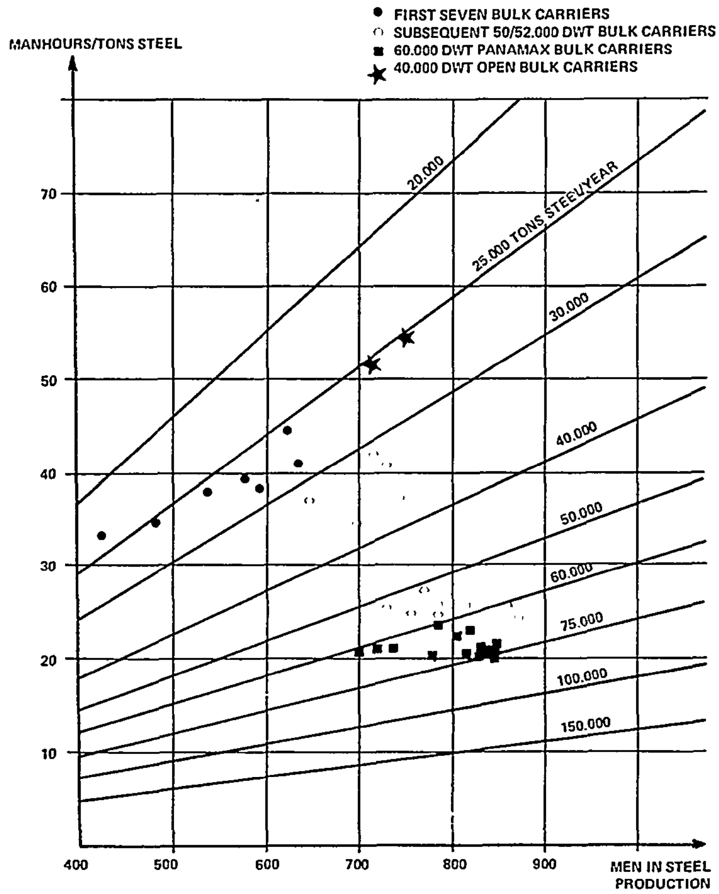



FIG. 7 RELATION BETWEEN MANHOURS/TS, STEEL OUTPUT AND WORKFORCE FOR BULK CARRIERS

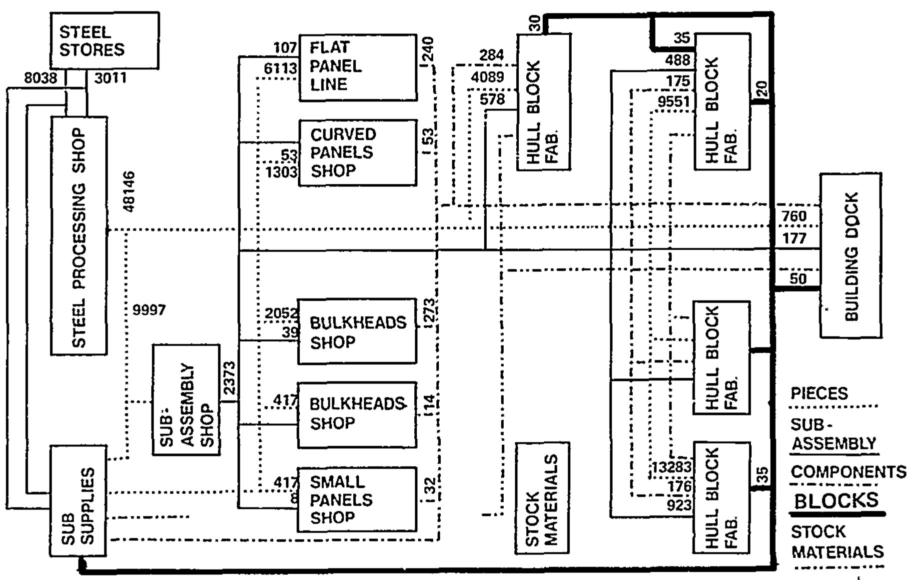



FIG. 8 MATERIAL FLOW CHART

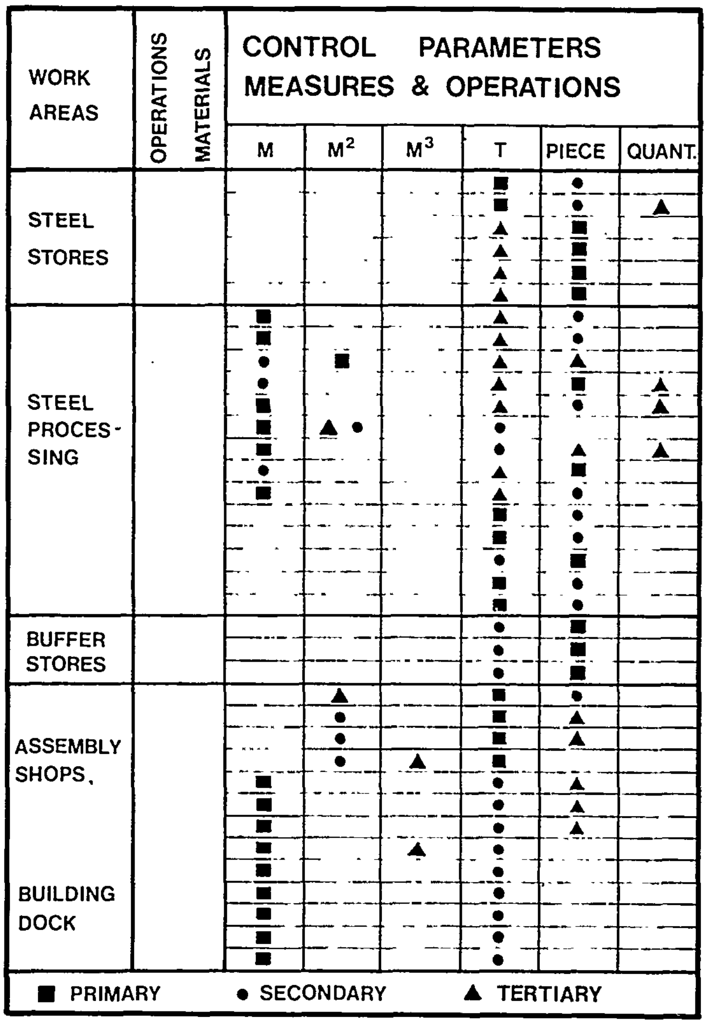



**FIG. 9 PRODUCT FLOW PARAMETERS**

Concluding these evaluations yard status as per 1972/73 is shown in Figure 10. The production capacity was restricted to 4 ships per year and the future target of 7 1/2 ships per year could be met only by the building dock.

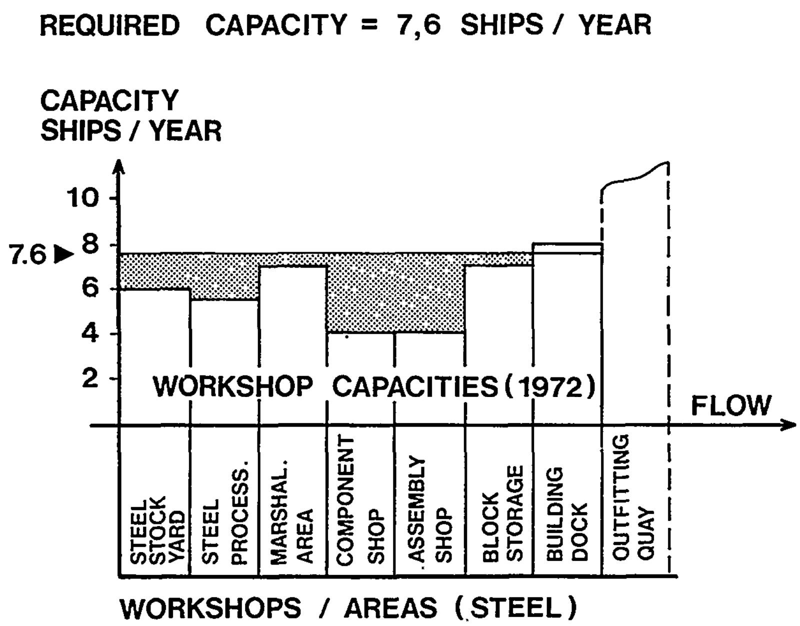



FIG. 10 CAPACITY PROBLEM BOTTLENECK

Production complexity for the bulk carriers in terms of manhours, production time and production area required is shown in Figure 11. As may be foreseen the fore and aft part is more labour intensive and requires longer production time, more crane coverage, supply service etc., than the parallel midship. This longer production time requires more space.

Cycle period is to be reduced, then average steel block weight and area under crane coverage must increase to facilitate increased throughput (as shown in Figure 12). The load on facilities can be levelled by dispersing work content to other and earlier stages. As shown by module production, Figure 13, or by tandem production, Figure 14, where labour intensive part of engine room for next ship is built in a separate location at the same time and building period as the ship to be launched.

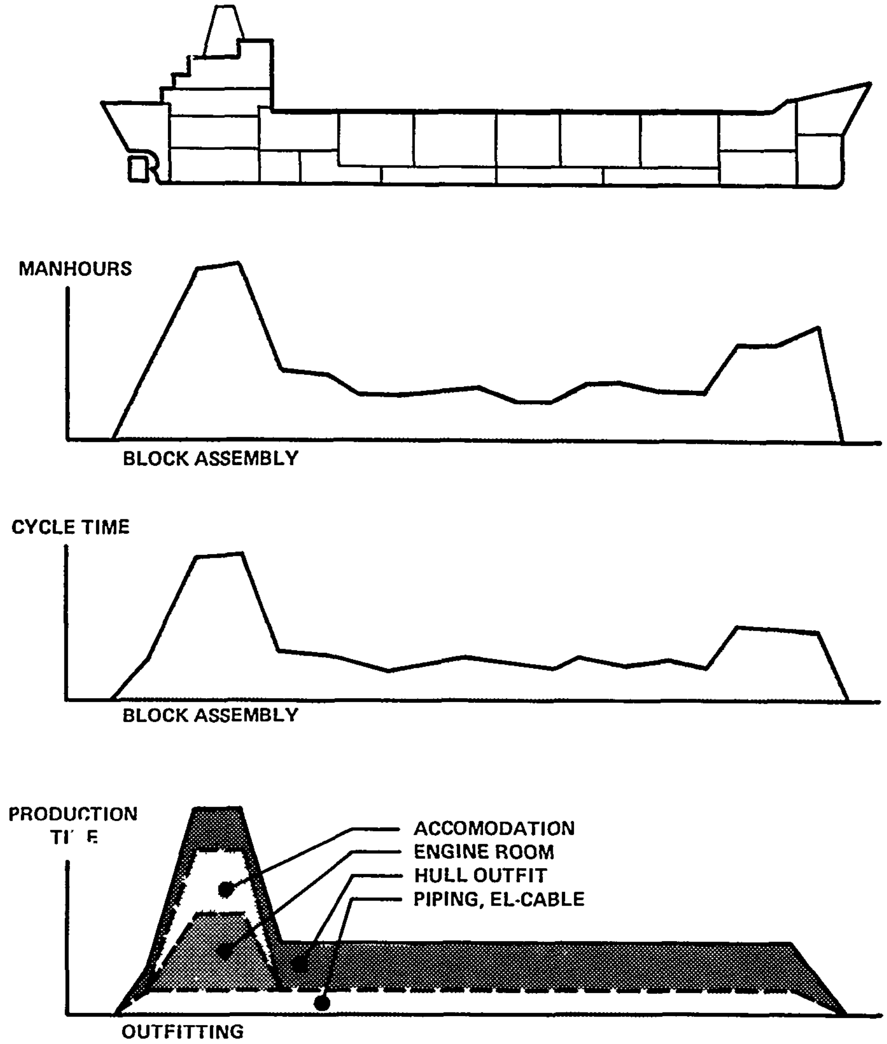



**FIG. 11 LOAD DISTRIBUTION FOR BC50**

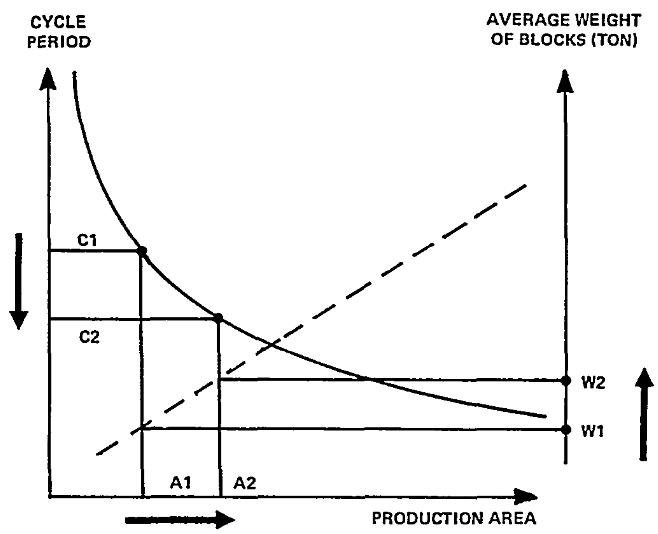
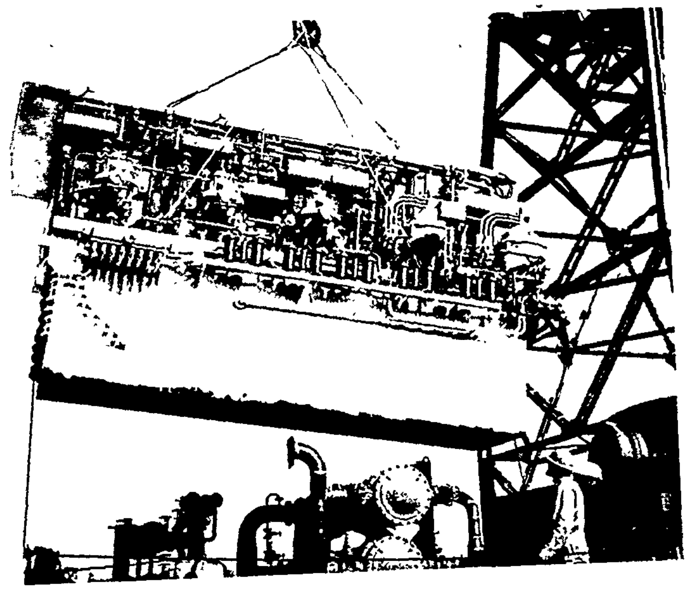



**FIG. 12 AREA/ACTIVITY DURATION/WEIGHT OF BLOCK**



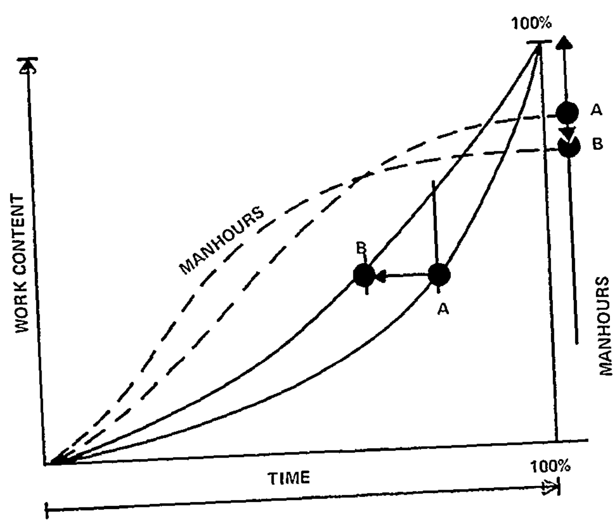
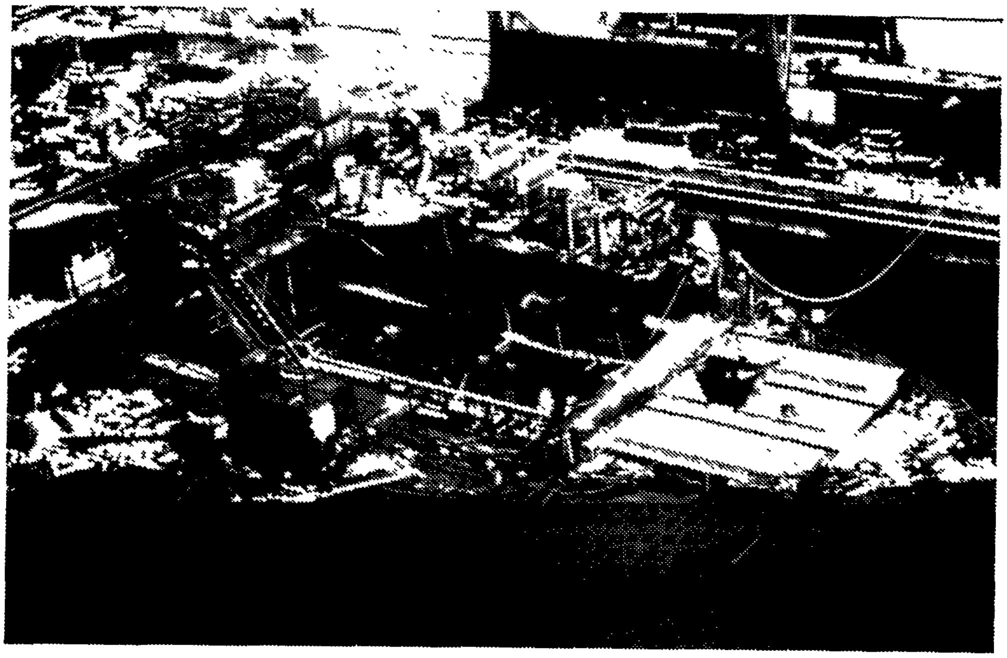



FIG. 13 MODULE PRODUCTION



ENGINE ROOM BLOCK IN DRY DOCK (STEP 2)

TANDEM METHOD
ENGINE ROOM BLOCK

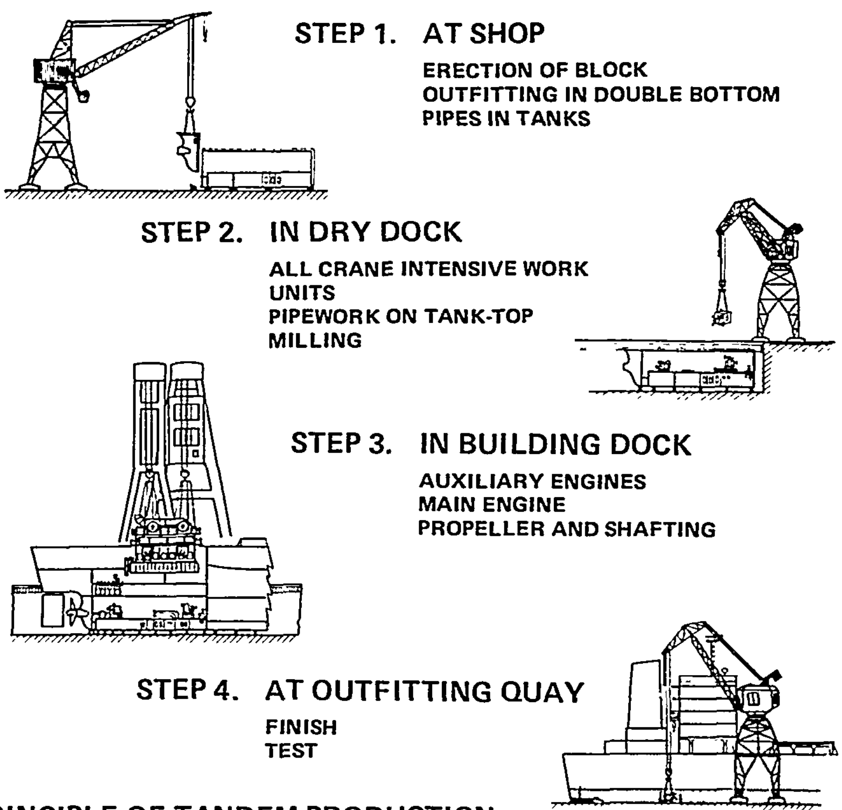
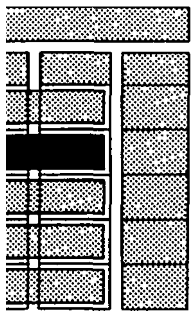


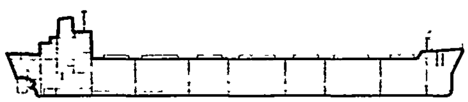

FIG. 14 PRINCIPLE OF TANDEM PRODUCTION

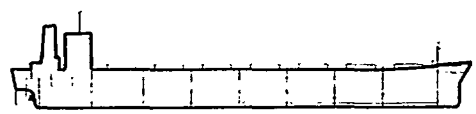
## 4. DESIGN SIMPLIFICATION



It is our experience that the greatest possibilities for productivity improvement are to be found at the design stage, not only at the time of making the working drawings, but also at the earliest stage of specifying the product. We were successful in the marketing of our 52,000 dwt bulk carrier and we could have sold many more. From our analysis we recognized, however, the necessity of simplifying the product and making it more suitable for production while maintaining or improving the service operating features of the ships.

Figure 15 indicates how the ships were simplified by removing forecastle and poop, box shaping superstructure, modulizing engine room, reducing number of blocks, standardizing hold and hatch sizes as well as double bottom height.





| 52.000 DWT | | 60.000 DWT | |
|---|---|---|---|
| STEEL WEIGHT | 7,900 TONS | STEEL WEIGHT | 9,000 TONS |
| NO. OF STEEL PLATES | 3,200 | NO. OF STEEL PLATES | 2,600 |
| NO. OF SHAPES | 8,000 | NO. OF SHAPES | 4,000 |
| NO. OF HULL PIECES | 51,000 | NO. OF HULL PIECES | 35,000 |
| WELD LENGTH | 155 MILES | WELD LENGTH | 125 MILES |
| PIPE LENGTH | 24 MILES | PIPE LENGTH | 16 MILES |
| ELECTRICAL CABLES | 25 MILES | ELECTRICAL CABLES | 26 MILES |

FIG. 15 SIMPLIFICATION OF BULK CARRIER DESIGN

Every part of the ship was redesigned with the purpose of making work easier even if steel weight had to be slightly increased. Figure 16 shows an example as to how such simplifications can be made on scantlings in double bottom, hopper and topwing tanks.

For many years Burmeister & Wain has possessed a computer system for developing single curvature ship lines and straight expansion of approximately 95% of hull surface. The hull form, somewhat untraditional from a naval architectural point of view, provides great simplification in workshop production, while maintaining excellent hydrodynamic characteristics.

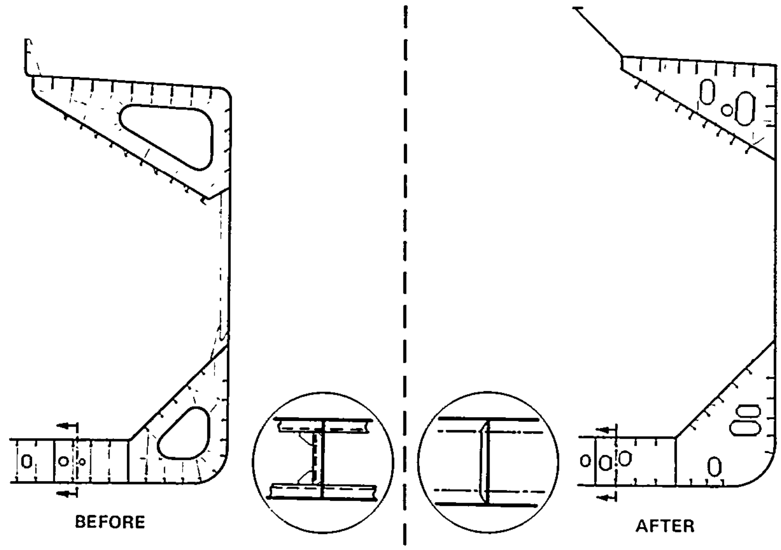
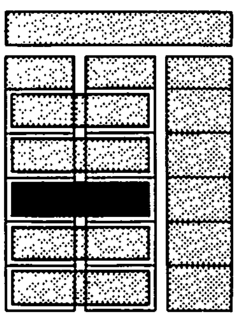



FIG. 16 MIDSHIP SECTION

## 5. INCENTIVE WAGE SYSTEMS



Burmeister & Wain Shipyard has for many years operated with incentive wage systems for blue collar workers. The ratio of fixed part of salary to bonus was in general 4:1 and the gross salary obtained on one ship was considered basis upon which bonus for next ship was to be negotiated (see Figure 17).

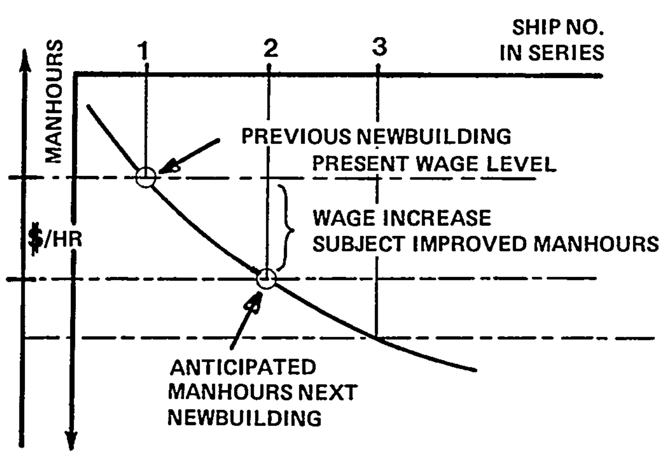



FIG. 17 PRINCIPLE OF WAGE AGREEMENT PREVIOUS SERIES OF BC50 AND BC60

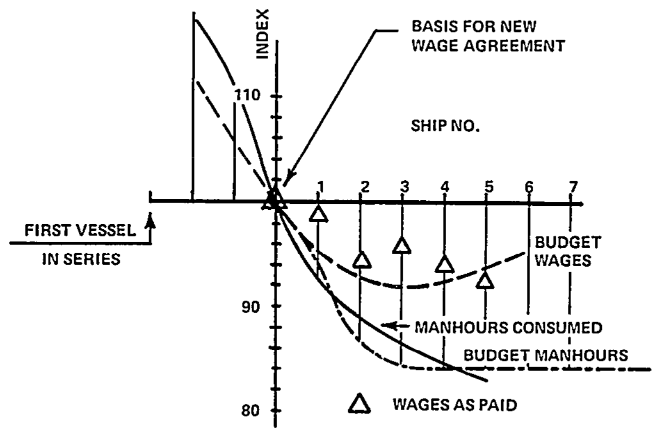
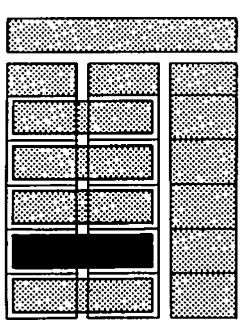



**FIG. 18 FIRST YEAR RESULT OF WAGE AGREEMENT PRESENT SERIES**

Incentive wage system alone will not improve productivity, but the system of having a carrot in front of the worker in our opinion makes him more benevolent in adopting systems of improvement. Admittedly it is difficult to adjust the distance as well as size and quality of the carrot. The administration of these wage systems is complicated, particularly at yards such as ours with 14 shop stewards. The effect of incentive wage systems on efficiency cannot be properly evaluated, but contrary to most continental yards we believe in the system, particularly after registering Swedish experience of 20-25% increase of manhours following the abandoning for political reasons of incentive wage systems.

In our present series of 18 ships we have succeeded in obtaining fixed agreement for 15 ships. Although somewhat premature for conclusions our results to date are promising (see Figure 18).

## 6. INVESTMENTS



Since the commissioning of the new facilities our yard has spent comparatively small amounts on investments (Figure 19) for the reason that savings in production costs could not justify financial costs at the high Danish interest rate. In solving our bottleneck problem we were, however, forced to increase our crane coverage in numbers more than lifting capacity to serve the exponential demand when increasing flow capacity.

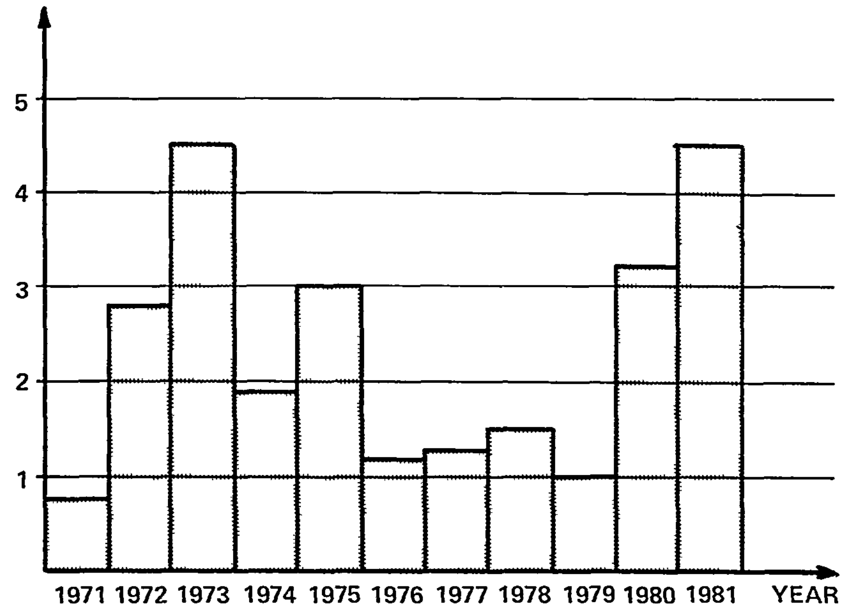


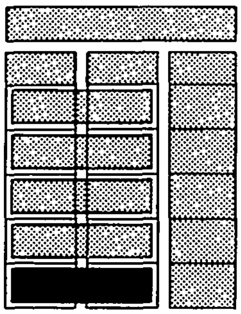

FIG. 19 INVESTMENT % OF TURNOVER

Adequately covered with the basic prerequisites of space and crane coverage, our investments policy has since been limited to purchase of minor equipment (such as automatic welding machines) and to development of new software systems. We do not believe in investments in sophisticated numerically controlled equipment for the early steel production stages, such as plate storage handling and plate and profile cutting workshops, for the simple reason that in a production process where 70% of the manhours are consumed in assembly halls and building dock and 20% in subassembly, limited effect on total picture can be obtained by substantial investments on reduction of the last 10% of manhours consumed in the plate handling and cutting process.

Further it has been seen in the past that such investments made to reduce manhours actually create new production flow obstructions. A Scandinavian yard of distinction invested in an automatic panel frame fitting machine that in 15 minutes with great accuracy and three string welding fitted the frames to the plates, only to discover they had created a bottleneck restricting yard output to 15 minutes per frame. The problem was solved by creating additional area outside where fitting was done by traditional gravity welding. Incidentally, Labour cost maintaining this machine surpassed labour saved in the new work process.

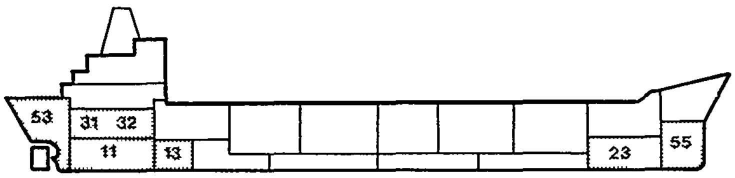
Our investment policy might be seen in respect to our building program and might indeed be different if we worked with different products and product mix.

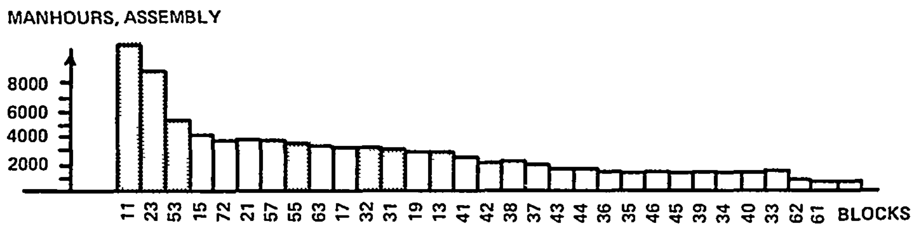
## 7. SUBCONTRACTING



Subcontracting is an activity frequently adopted in the Western hemisphere. Some Japanese shipyards consider shipbuilding to comprise only two basic activities: steel production and logistics.

Subcontracting as compared to own production is elementary in respect to evaluating cost of manhours and efficiency, but perhaps more difficult when evaluating relief on facilities and resources that can then be relocated to more suitable work.



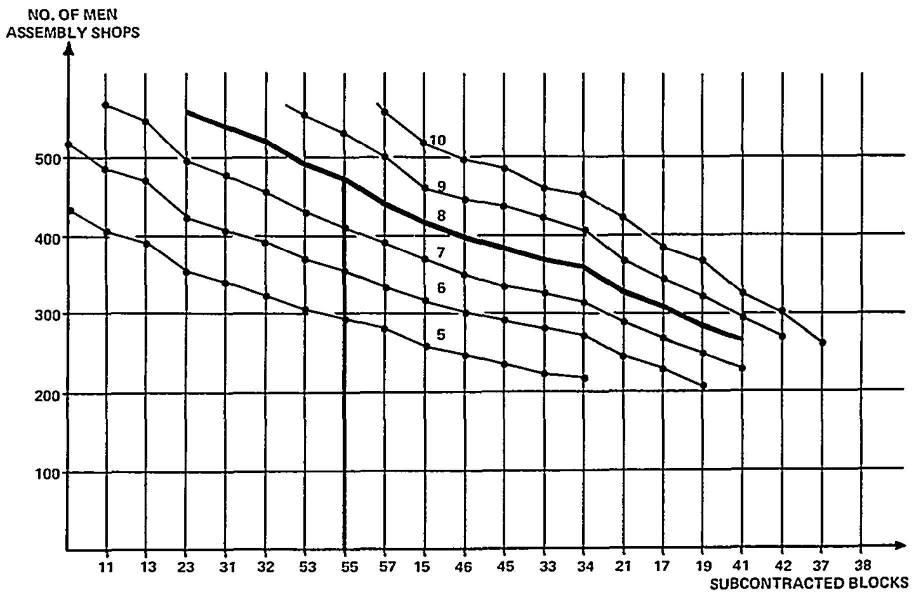




FIG. 20 & 21 NO. OF BLOCKS SUBCONTRACTED FROM ASSEMBLY SHOPS WITH EFFECT ON PRODUCTION FLOW FROM ASSEMBLY SHOPS

With reference to Figure 11, ship block production manhours can be split up as shown in Figure 20. By subcontracting labour intensive work which requires a heavy load on workshop facilities, e.g. block 11, resources can be allocated to easier blocks. Figure 21 indicates in theory how production flow of ships can be increased by subcontracting blocks provided of course that building dock facilities are sufficient to assemble blocks at required rate.

## 8. CONCLUSIONS

The result of our efforts are shown in Figure 6, Figure 7, on percentage basis Figure 22, and Figure 23.

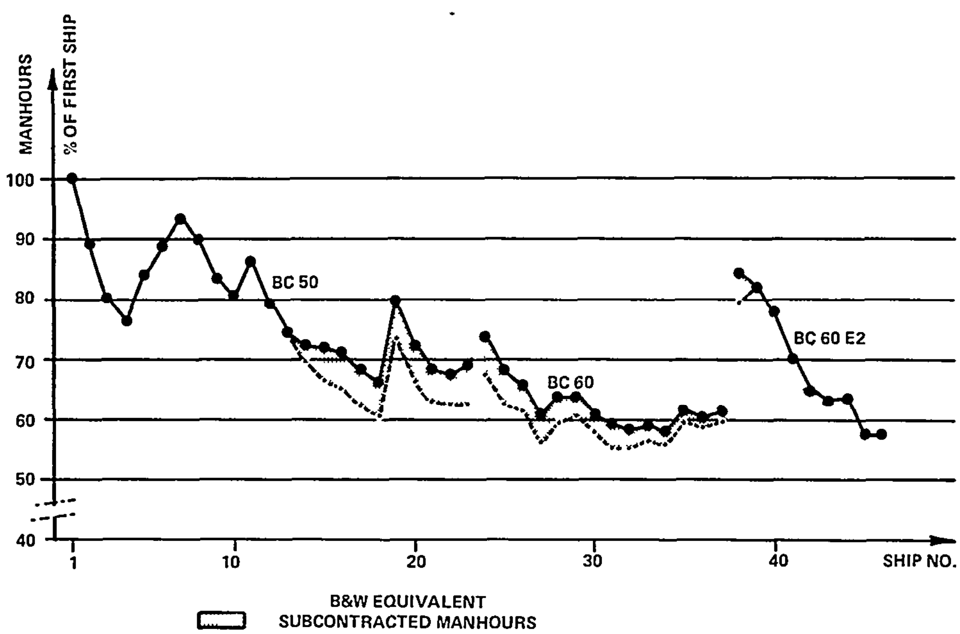



FIG. 22

When evaluating means of improving productivity particularly in respect of increasing the throughput, the cost of administration and control must be taken into consideration.

Our yard operates on a fixed price basis with no adjustments except for extra equipment and our accounting system is based on invoicing at delivery. This means that profit is turned to account only when a new building is delivered.

Our indirect costs are considered on shipyard year total only and are hopefully adequately covered by sum for contribution margin for the number of new buildings delivered that year. By increasing output, required contribution margin per newbuilding can be reduced, however, an increased production rate will require increased indirect costs (Figure 24).

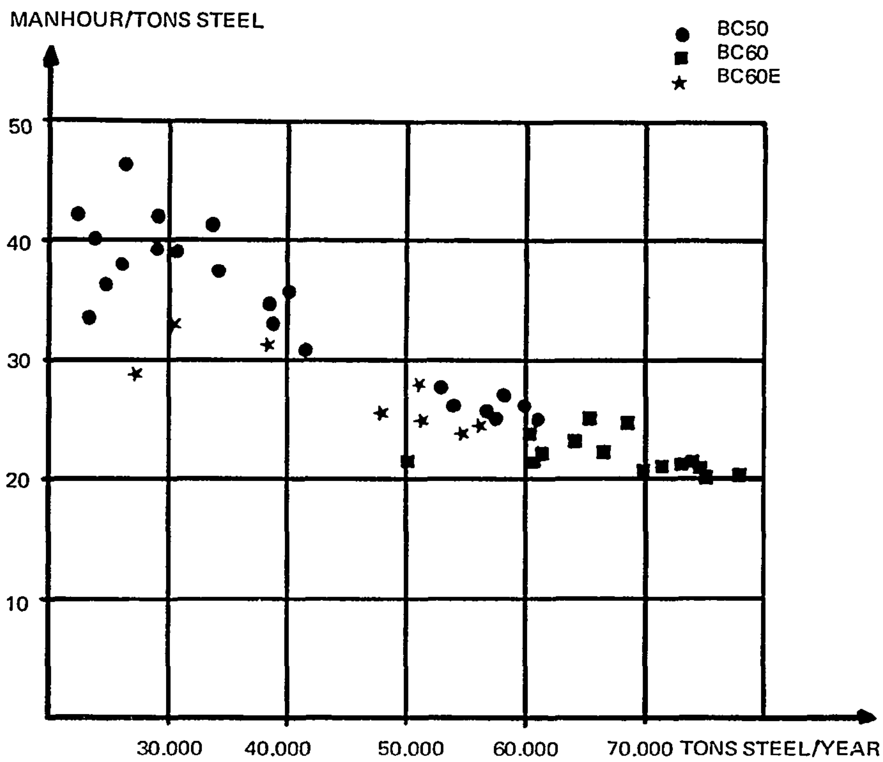



FIG. 23

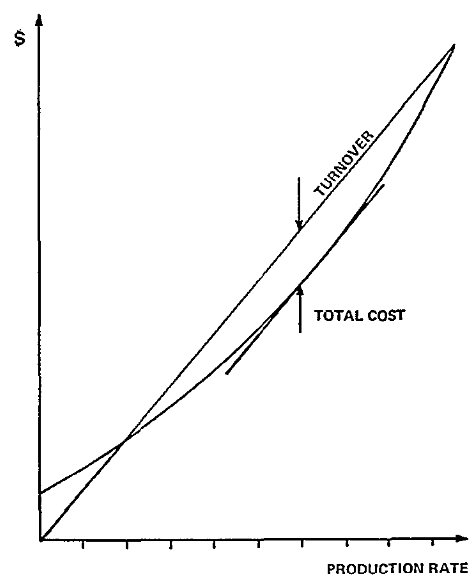



FIG. 24 RELATION COSTS/TURNOVER

At our peak production period of 1976/1 977 we were close to a production rate of one ship launched from our newbuilding dock very 25 working days, and such highly geared activity requires considerable attention to planning, follow up and quality control, both of equipment and production.

Our yard has presently geared down to a production rate of 5.4 ships per year due to market considerations and a policy aimed at limiting the sensitivity of the labour force to a fluctuating market.

Labour force and staff reduction compared to production can be summarized as:

| Year | Labour Force Average | | Staff★ | | Production Panamax/Year | |
|---|---|---|---|---|---|---|
| 1976/77<br>1982 | 2000<br>↓<br>1400 | 30% | 570<br>↓<br>290 | 49% | 7.6<br>↓<br>5.4 | 29% |

* Excluding department of Shipbuilding Services providing ship designs to other yards around the world.

Having virtually been at a stand-still in 1979 with only 950 workers employed, it has meant some difficulties to get the yard restarted even to the lower production target. Our present efficiency is approximately as previously attained, but we have experienced that this efficiency is more difficult to achieve at a lower production rate. This, however, is a topic we might revert to in the future, when we have finished our present series.

# PARTGEN: AN ADVANCED INTERACTIVE METHOD FOR HIGHLY AUTOMATED PARTS GENERATION BASED ON THE DESIGN MODEL DATA

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Shipping Research Services
Oslo, Norway

Mr. Cuilenborg has 19 years of shipbuilding experience, 14 of those years with Shipping Research Services in Norway.

## ABSTRACT

This is a brief introduction to the present status of the AUTOMODL development effort (AUTOKON) and an indepth description of the first module of an AUTOMODL named PARTGEN. PARTGEN works on a topological model of the ship and is stored in the database. PARTGEN uses extensively interactive graphics and will virtually eliminate 90 percent of what today is called partcoding in the production phase. In addition to performing part generation, PARTGEN also has other valuable functions. It can do fairing of lines, interactively, to establish a preliminary hull form for building up the design model in the database, It has a report generator whereby the user can make extensive reports from the database and make user formulated layouts on the reports. PARTGEN also includes extensive automatic updating procedures due to changes. This is a benefit of having parts for production stored as topological data instead of as geometry.

PARTGEN

The first module in AUTOMODL

<u>Introduction</u>

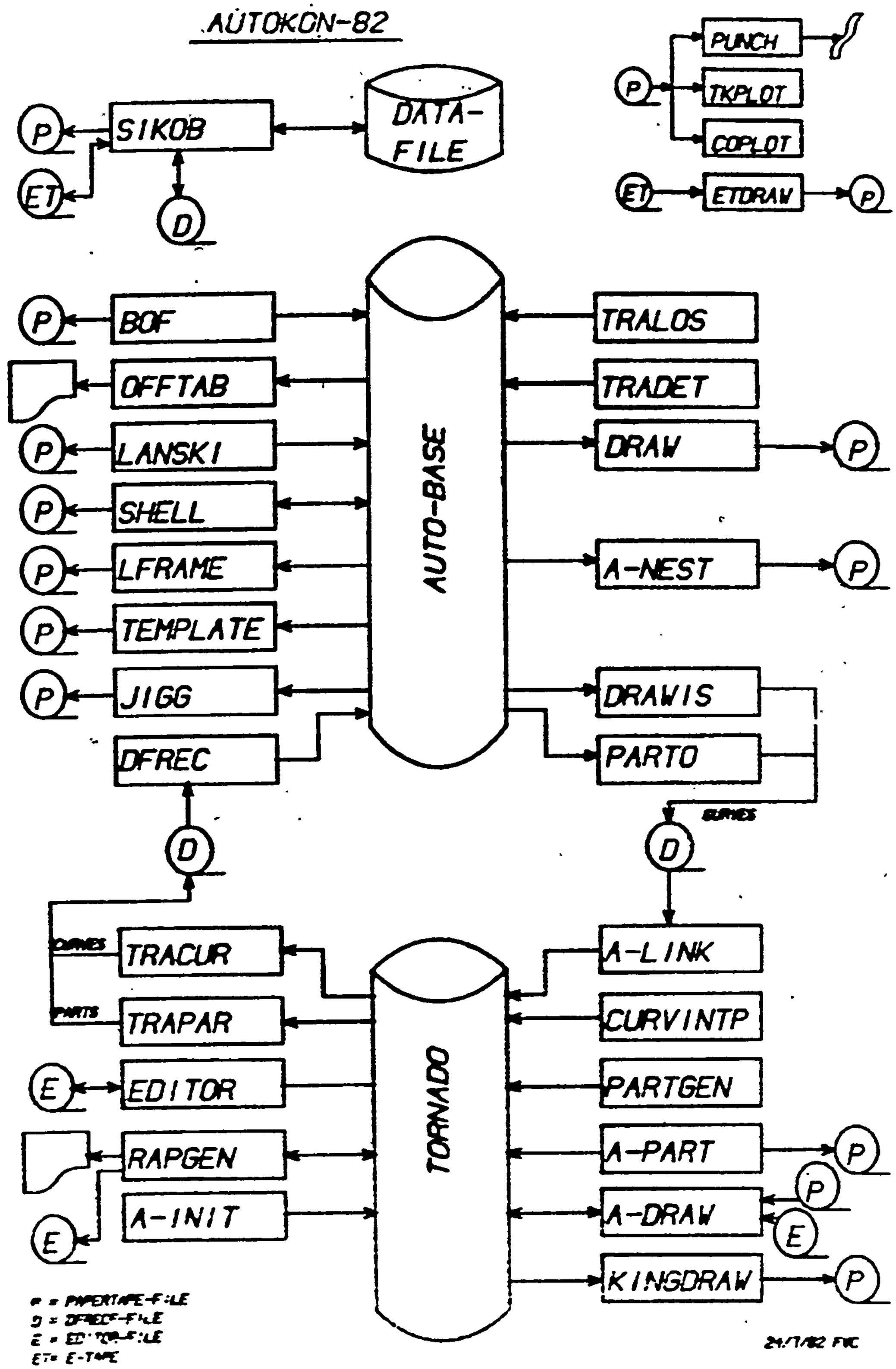
PARTGEN is the first available module in AUTOMODL. It is using the new Database system TORNADO which will be the common database for AUTOMODL. PARTGEN is an interactive tool to define steel structures in plane surfaces. The PARTGEN module can be used in three different ways.

0 PARTGEN can receive curves from other programs. These curves will then form various surfaces, and these surfaces will be in various stages of completion depending on the detailing-level done with other programs. These curves may include boundary curves for the surfaces (edges), intersection curves, trace curves (stiffener traces),seam curves and curves with cutouts.

0 PARTGEN can also build up the structure within a surface using available commands and macros.

0 PARTGEN can also be used as a combination of the two above. This will typically be the case when the structure is only partially finished before PARTGEN is used.

The regular output from PARTGEN is production parts ready for nesting. However, output or information is also stored in the database, and various reports can be generated as regular output.
Output from PARTGEN can also be used by AUTODRAW for,generation of drawings.


AUTOKON-82
SIKOB
DATA-FILE
PUNCH
TKPLOT
COPLOT
ETDRAW
BOF
OFFTAB
LANSKI
SHELL
LFRAME
TEMPLATE
JIGG
DFREC
AUTO-BASE
TRALOS
TRADET
DRAW
A-NEST
DRAWIS
PARTO
TRACUR
TRAPAR
EDITOR
RAPGEN
A-INIT
TORNADO
A-LINK
CURVINTP
PARTGEN
A-PART
A-DRAW
KINGDRAW
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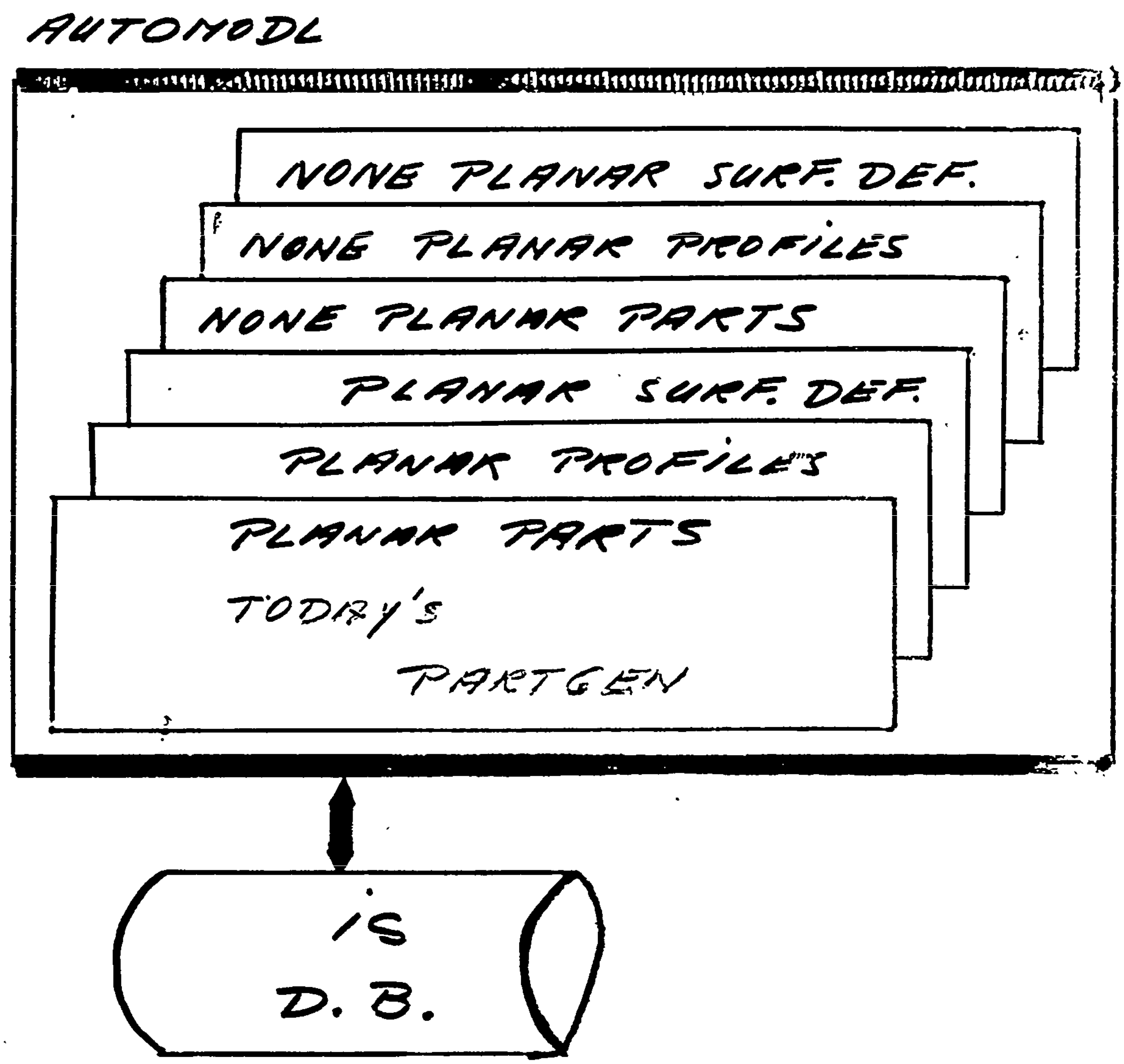
# PARTGEN IN AUTONODL



Systemphilosophy

In PARTGEN there are several basic consepts that need some explanation.

0 Product. A product in PARTGEN is the entire sturcture the user wants to work with. It can be an entire ship, a half ship or a group of units. A product is normally given a name like YN 228AB. A project identification (Project number) is also linked to the product.

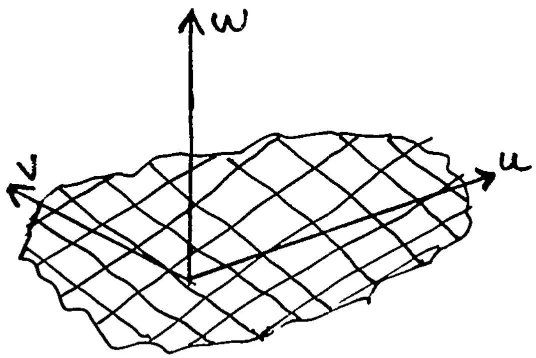
0 Surface. A product is built up of various surfaces. A surface is defined as a U, V, W-coordinate system, related to the global X, Y, Z system.
The surfaces in PARTGEN are given names by the user. The naming-conventions made so far should be familiar. PARTGEN is using names like: SHELL, DECK, PLTF, STRINGER, GIRDER, TFRAME etc.

0 Curves. A surface is built up by various curves, and a particular curve is always within a surface. These curves may be generated by PARTGEN itself, or they may be comming from other programs like BOF, TRALOS, TRADET etc.
There are several types of curves, and each curve has a name (type) and a numeric identification number.
The type of a curve also indicates what kind of curve it is. We have HOLE-CURVE (holes), SEAM-CURVES (seams, butts), TRACE-CURVES (traces of stiffeners), INTERSECTION-CURVES (curves formed by two surfaces intersecting each other) etc.

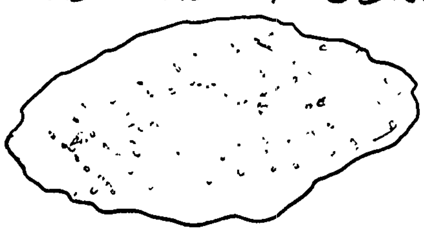
The three above mentioned consepts form the basis for part-generation with PARTGEN. Except for the Product, the user is free to manipulate surfaces and curves at any time in the PARTGEN process, thus being able to take care of last minute changes.

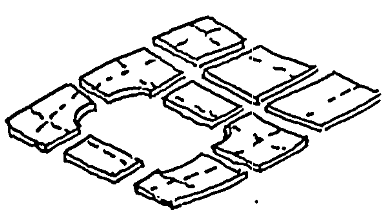
# CONSEPTS AND RELATIONS

SURFACE (PLANE SURF.)

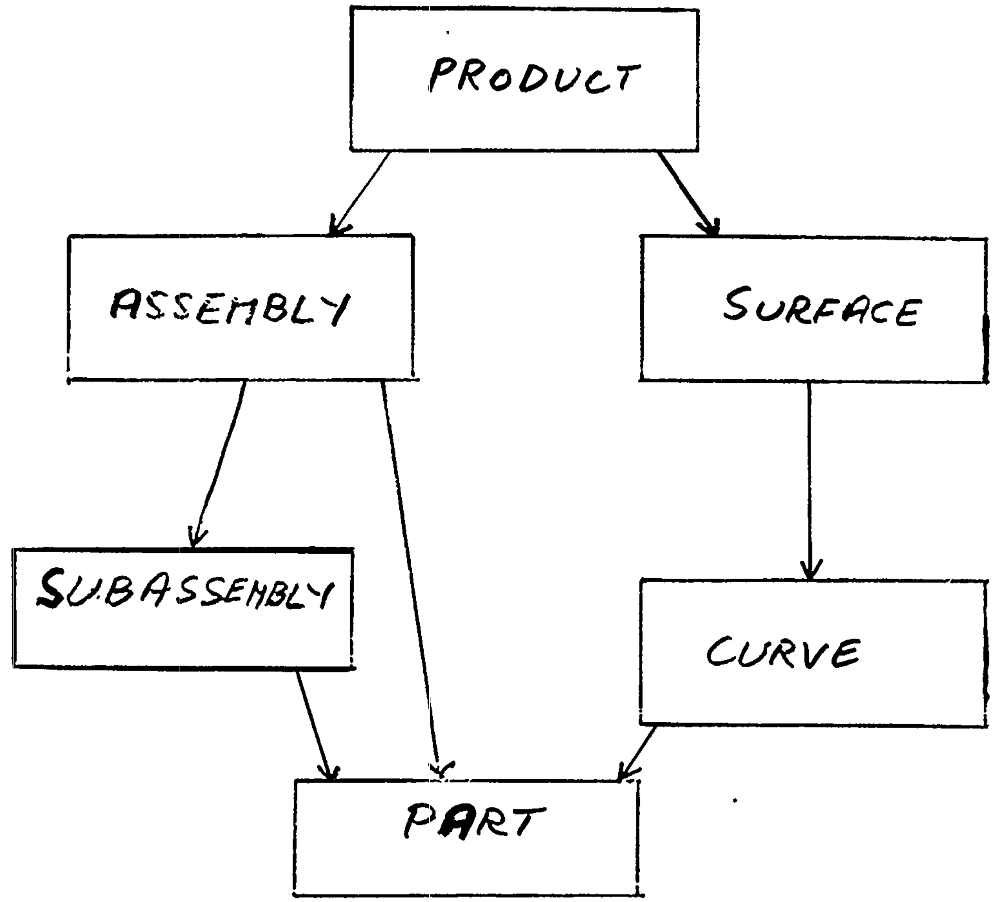



CURVES IN A SURFACE

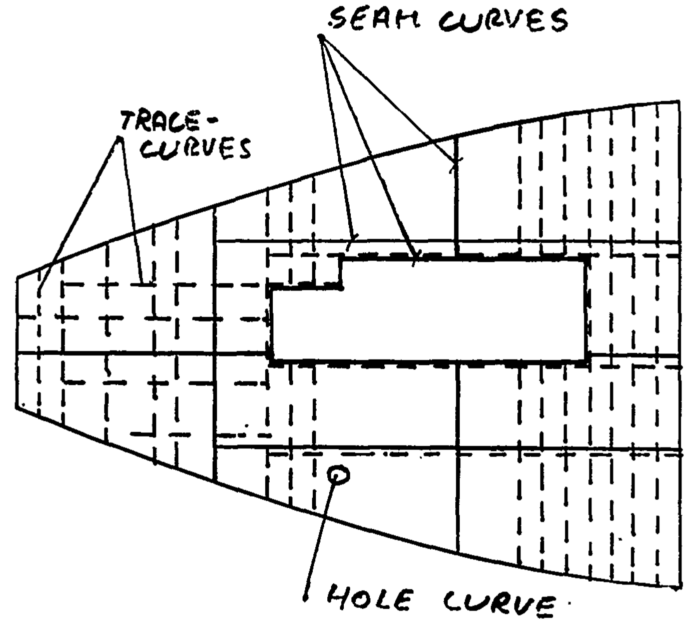




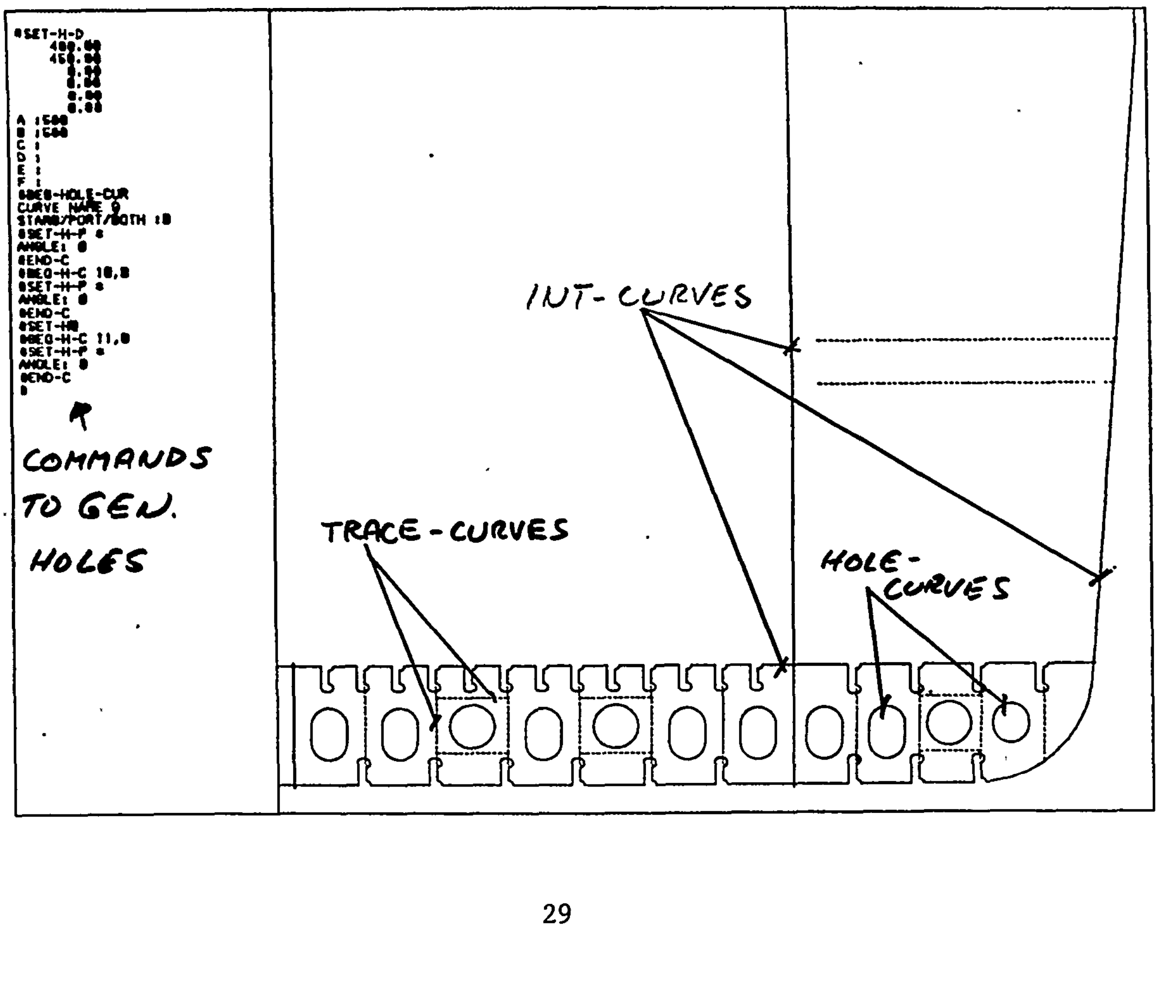
PARTS



# CURVES IN A SURFACE




ALL CURVES COMMING FROM TRALOS/TRADET/ISDRAW
ALL CURVES CAN BE MODIFIED OR DELETED BY PARGEN
NEW CURVES OF ANY TYPE CAN BE ADDED BY PARGEN



0 Assembly. The assembly consept is used when PARTGEN is used for generation of production parts. The user can establish a tree structure with assemblies and subassemblies, where the assembly normally will be a block or unit. The assemblies have identification numbers as also the subassemblies have. An assembly or subassembly is built up by parts for production. A part can not be defined without belonging to an assembly.

0 Parts. Parts are defined in PARTGEN as.belonging to an assembly or subassembly. One particular part will recide in a surface and contain various curves, also belonging to a surface.

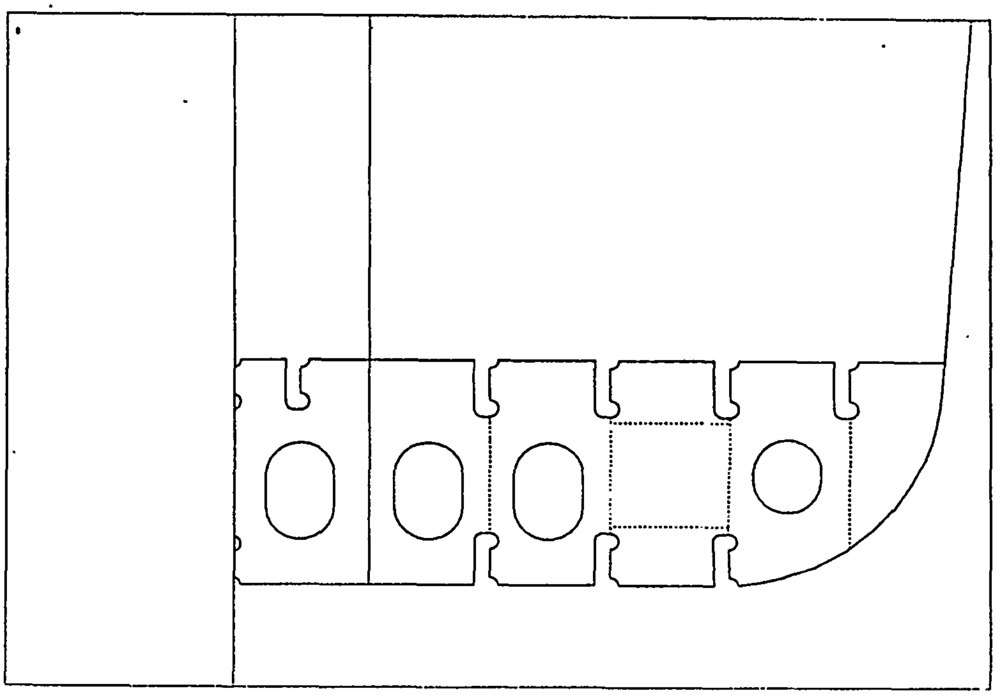
PARTGEN is not a part splitting programs. It does not even have any part splitting capability. PARTGEN is using intersection points between curves to generate a part. The part is built up by topological points formed by the intersection points between the curves. This consept makes automatic updating of parts based on modifications to curves easy.

How PARTGEN works

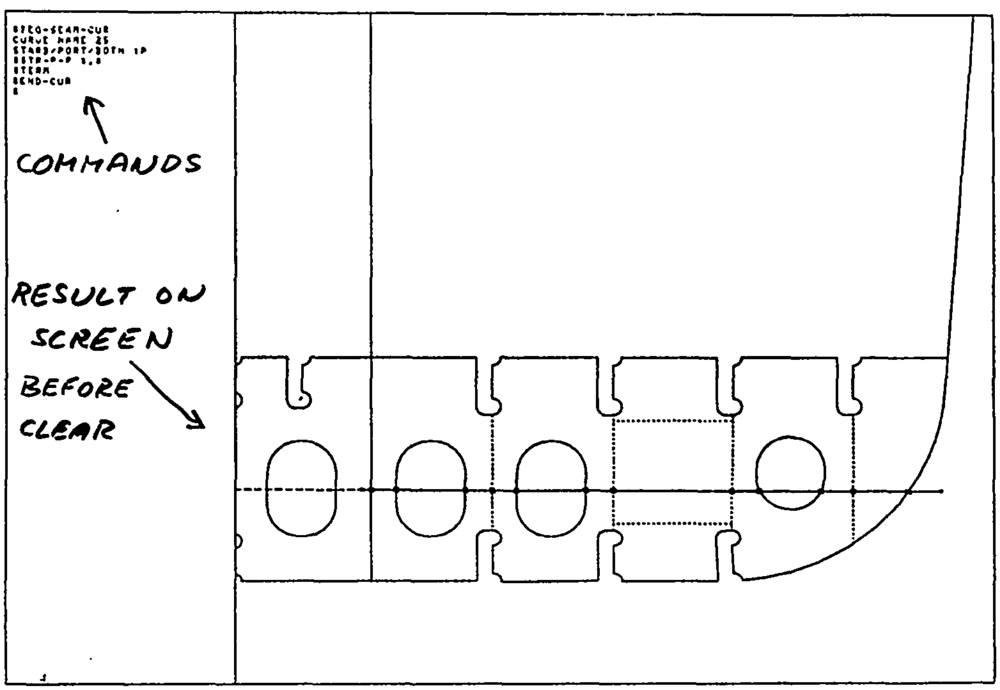
Normally, the PARTGEN process will start up after, or at the end of building up the model of the structure in the database. The building up of the model in the database is today done by the programs BOF, LANSKI, TRALOS and TRADED. These are traditional batch oriented programs. However, they are not run as batch programs today. All the traditional waiting time in a batch environment has been eliminated by running the programs on-line on a minicomputer from a graphic screen (terminal) like Tektronix or LSI-ADM 32. Quick verification and response to changes are key words in this context. In the near future, the complete model build up in the database will be done by other AUTOMODL modules. Today, parts of the model can also be built up by PARTGEN.
The initial bulk of data belonging to the model is transferred to the PARTGEN database by the programs DRAWIS and AUTOLINK.

From the PARTGEN database the user will bring up a particular surface or group of surfaces on the screen.
This can be the whole surface or only a window of it. Normally a window is used for better clearity. If-the surface is complete the partgeneration process starts imidiately. However, if additional seams or holes have to be generated, this is now done with PARTGEN directly and included in the surface and stored in the database.
The actualpartgenaration is done by using the crosshair to point at intersection points of curves that form the boundary of a particular part. However, before the actual partgeneration takes place, an assembly must be started by the command BEG-ASS name. Every curve that is inside the part will be included. This includes holes and traces of stiffeners. By the crosshair pointing, the topology of the part is generated.

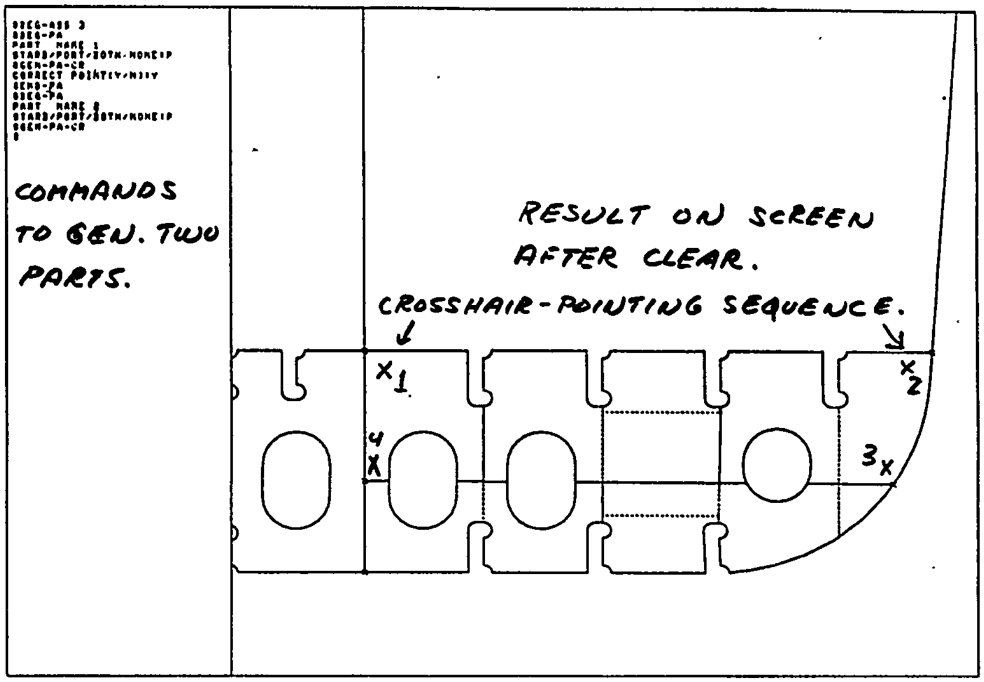
## ZOOMING OF DETAIL FOR PARTGEN



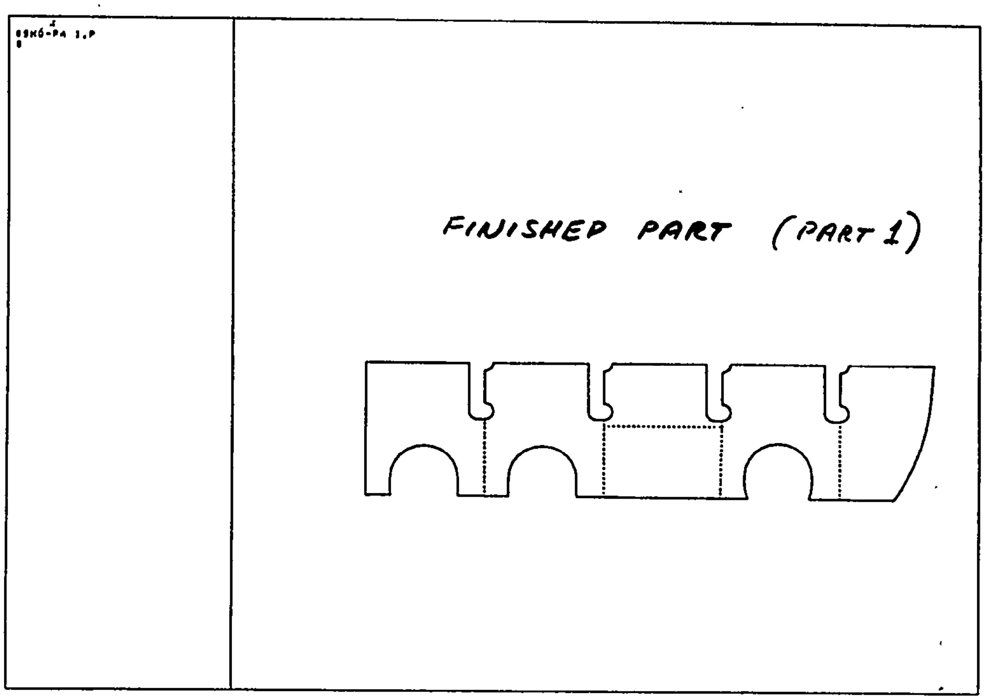
## SEAM-CURVE GENERATION



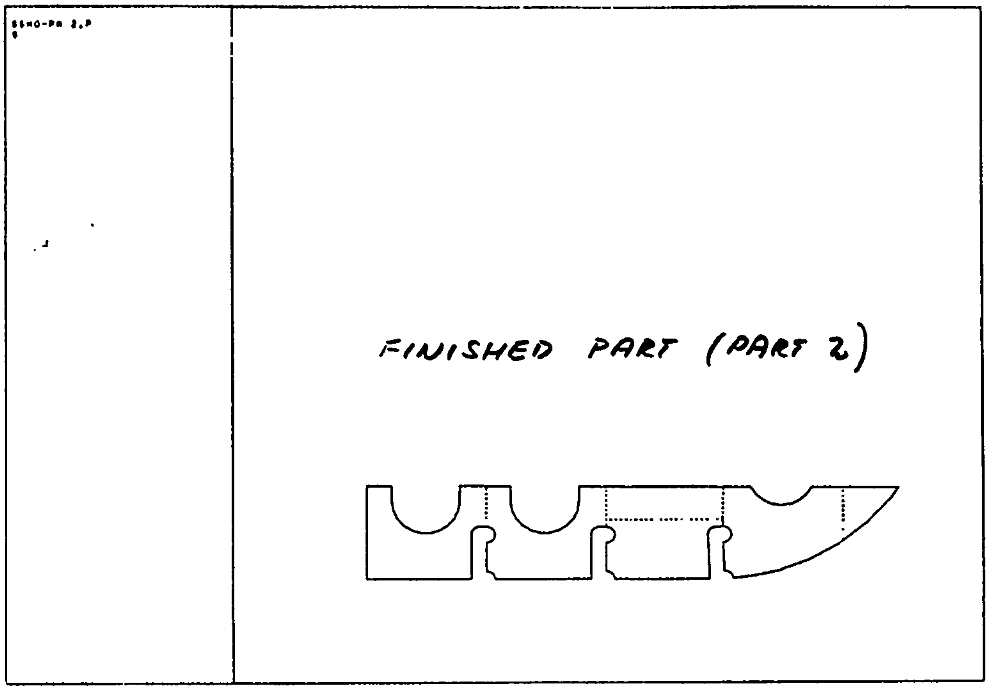
## PART GENERATION




## PART GENERATION



PART GENERATION

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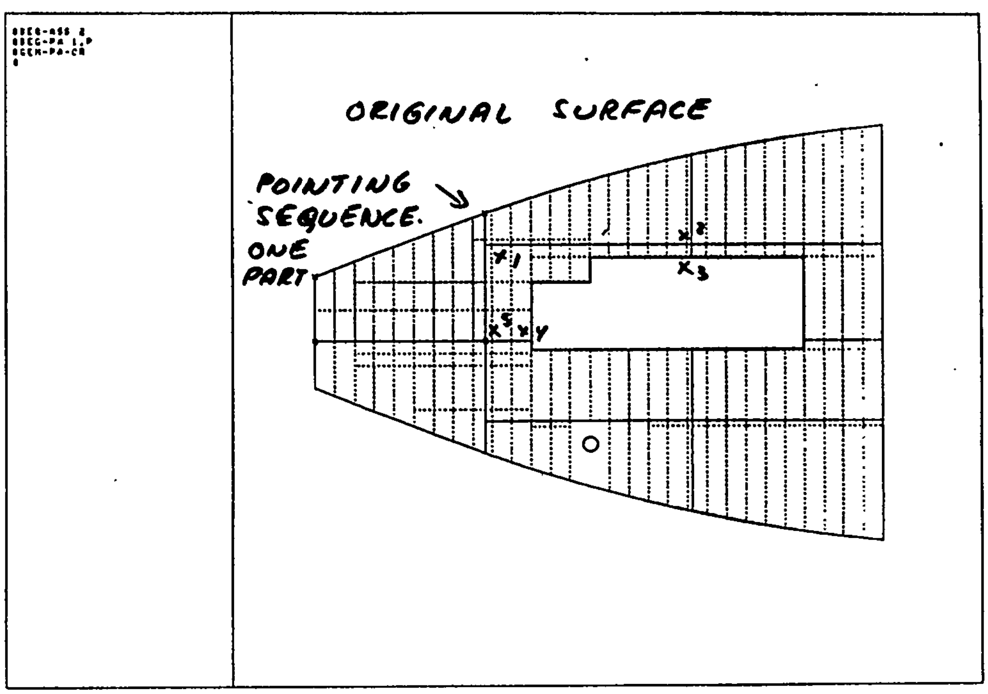

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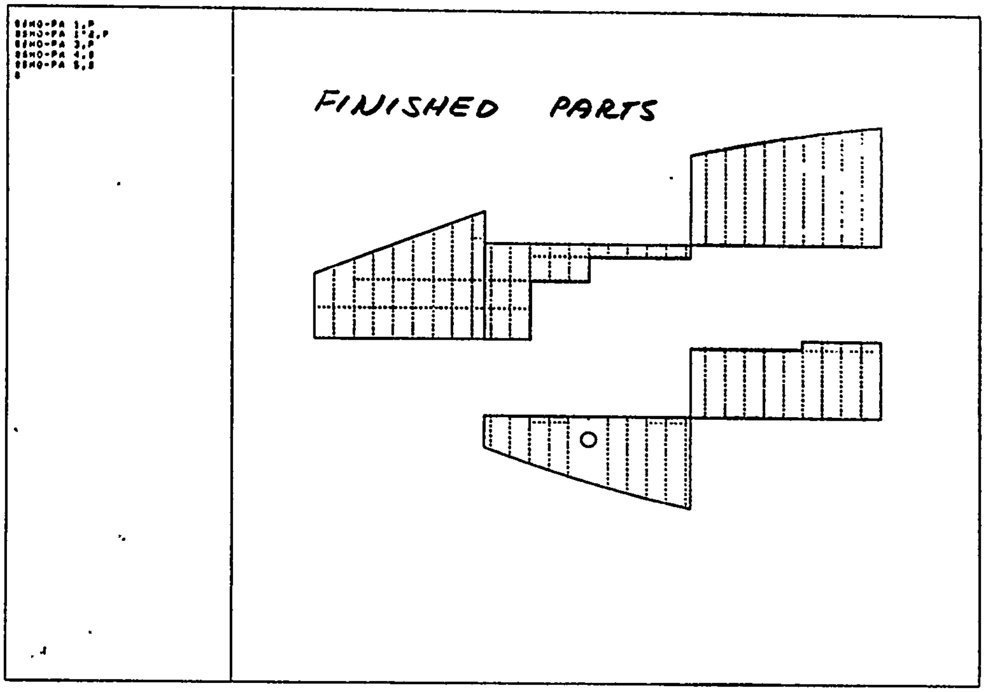
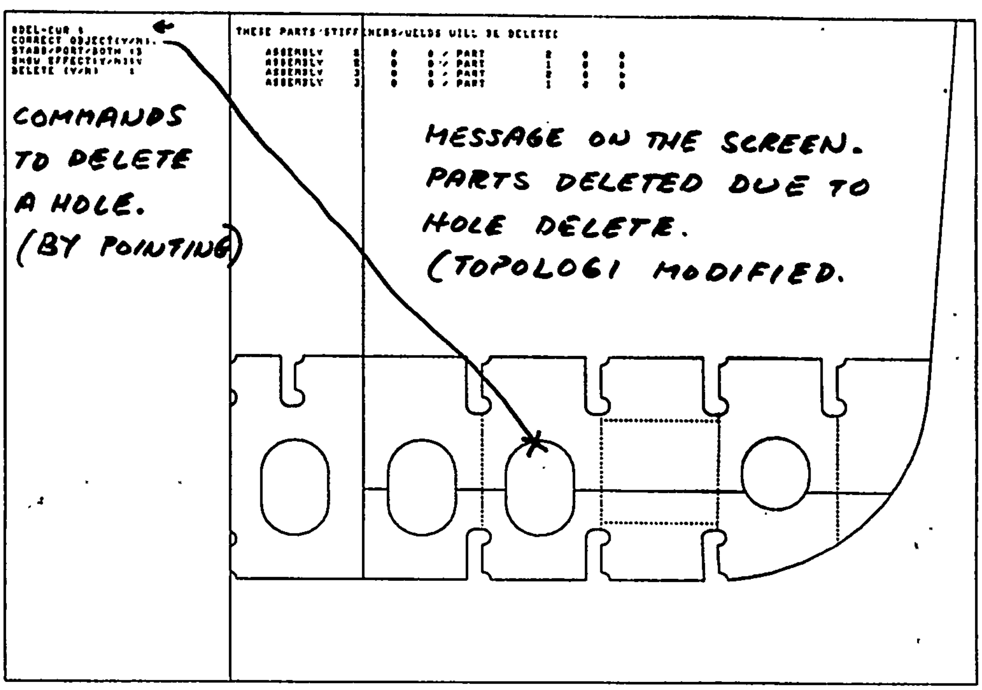



## PART MODIFICATION



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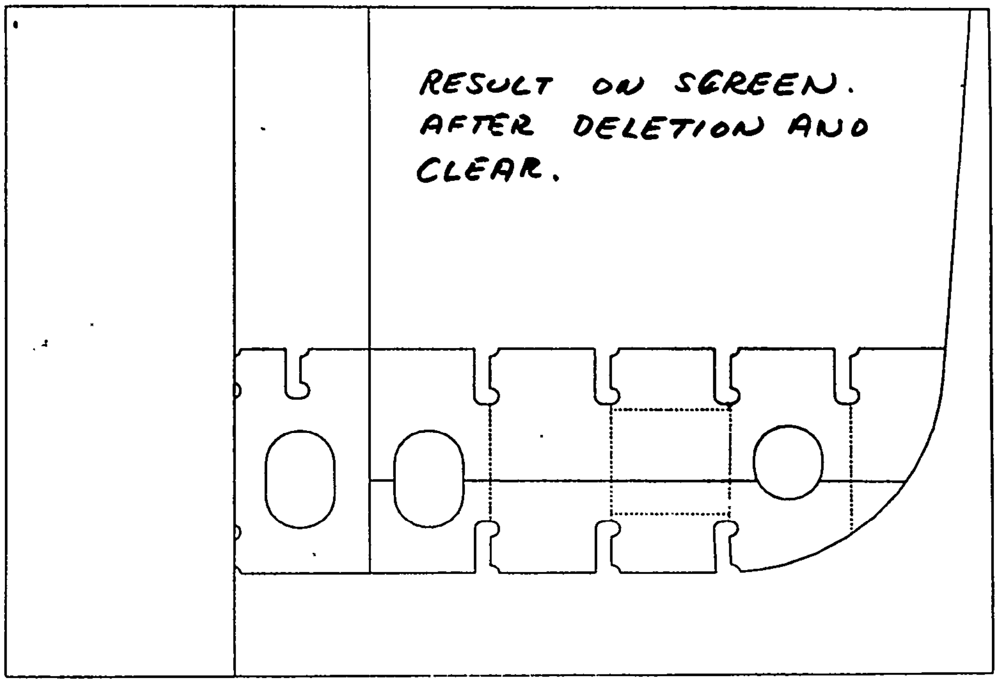


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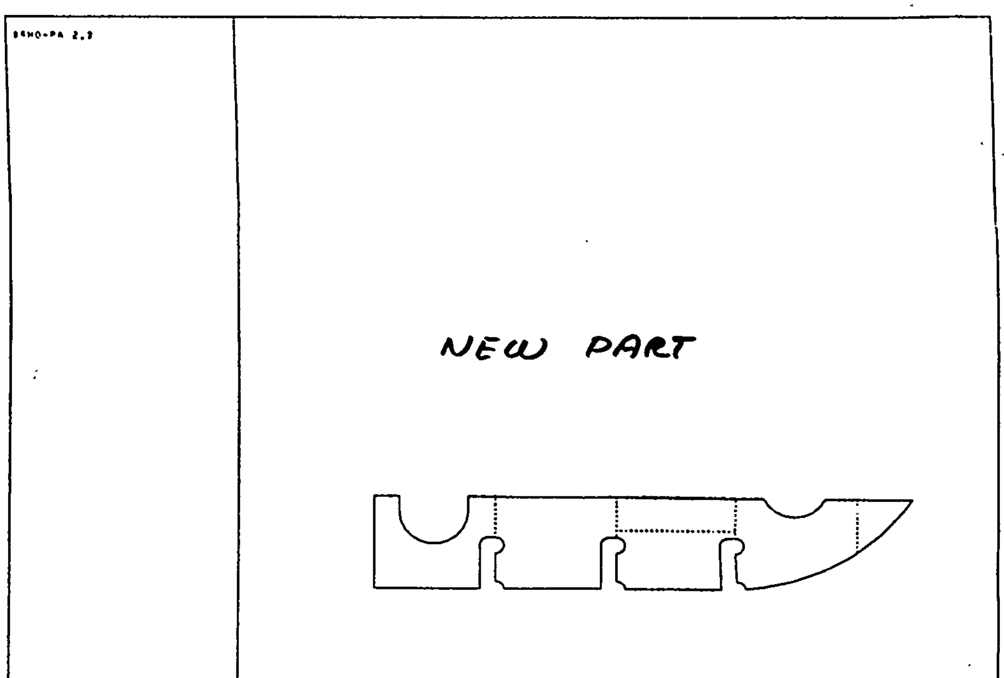

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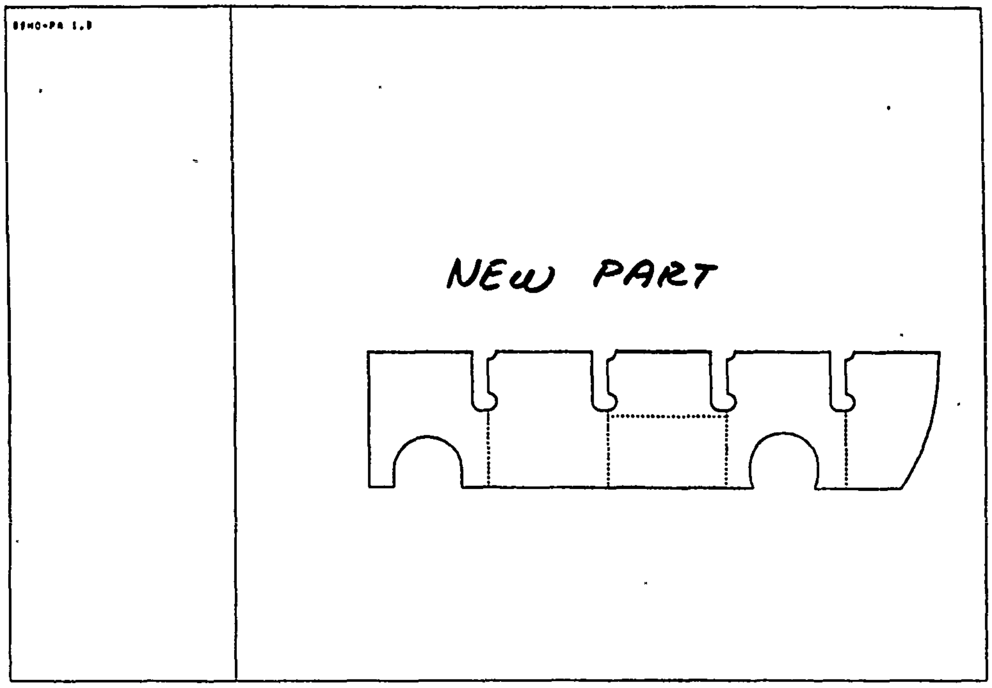


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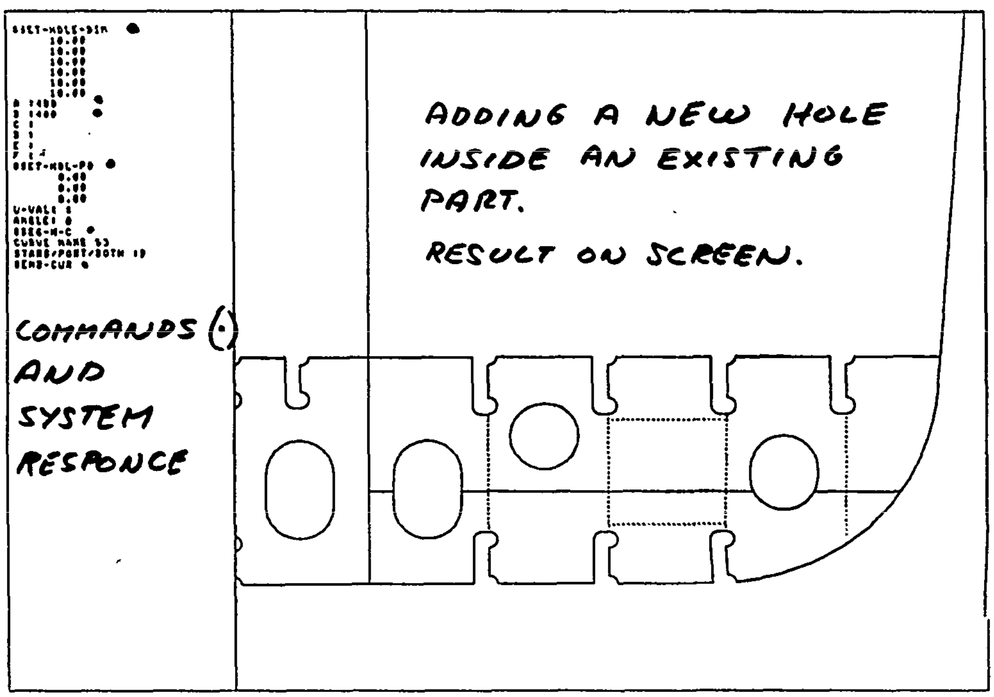

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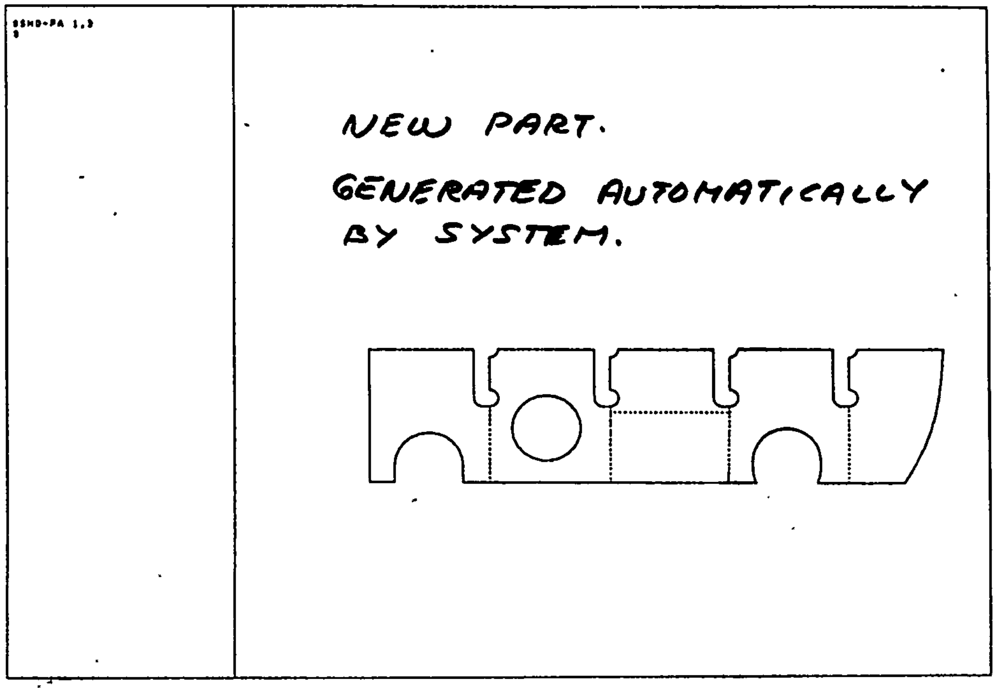
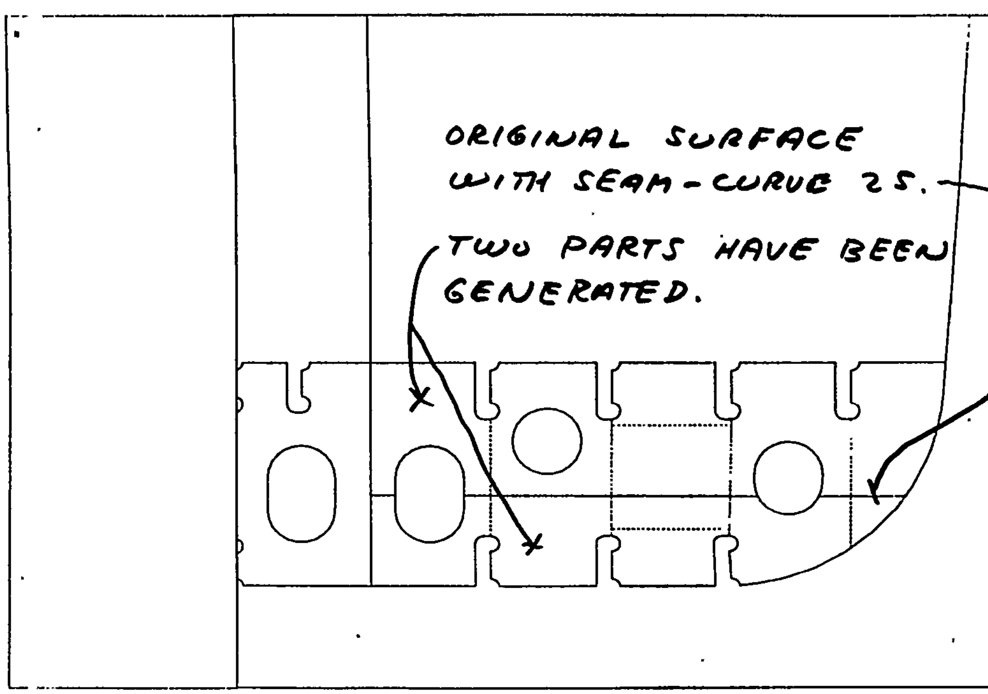
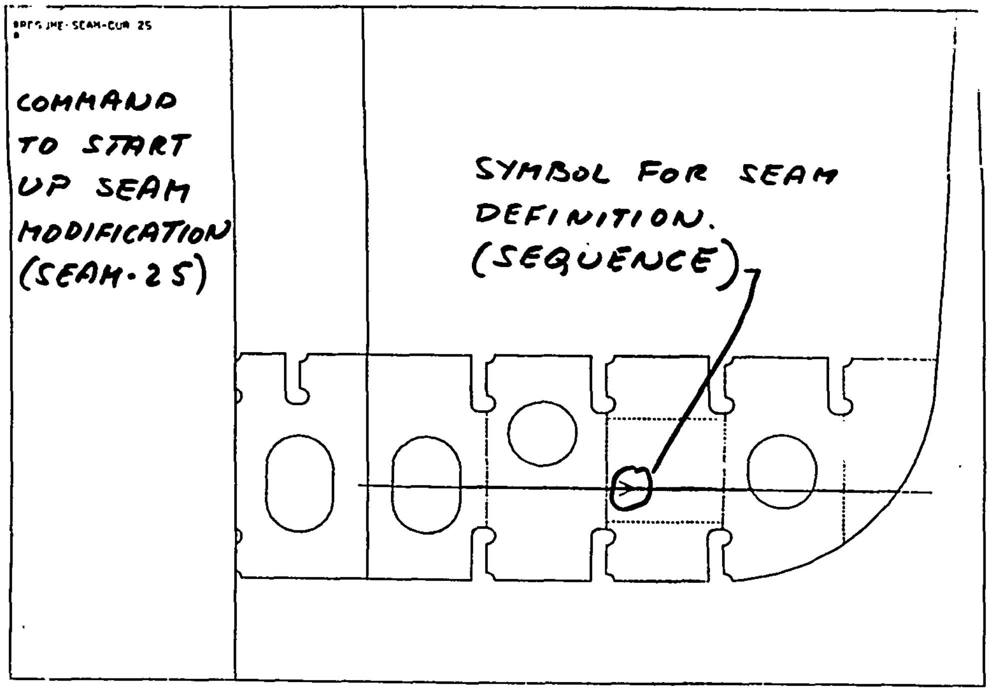


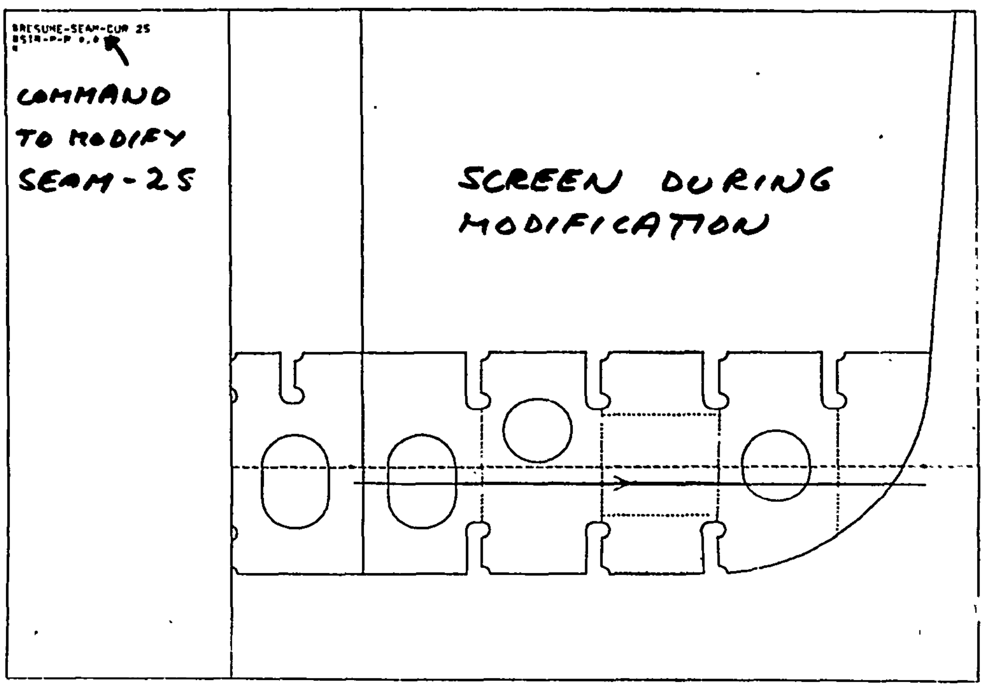

## PART MODIFICATION



PART MODIFICATION




PART MODIFICATION

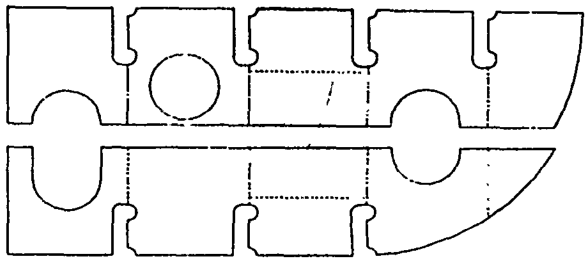


# PART GENERATION

```
STARB/PORT/BOTH/NONE:B
$SHO-PA 2

$STOP
--DATABASE IS NOW COPIED.--
STOP BY USER
CP 1362 BLOCKS
LI  112 BLOCKS
*PA 1824 BLOCKS
**** STOP
OK,
```

THE TWO NEW PARTS GENERATED AUTOMATICALLY BY SYSTEM.



# REPORT FROM PARTGEN

DO YOU WANT TO CONTINUE (OR SKIP) (Y/N/SK) ....... 1

ASSEMBLY - 01 MAI-13-1982

| PARTS-NAME/NUMBER | | | | THICKN. MM | AREA M2 | WEIGHT KG | COG. X | GLOBAL COG. Y | COG. Z |
|---|---|---|---|---|---|---|---|---|---|
| PART | 11 | 0 | 0 | 15.00 | 5.58 | 651.42 | 11958 | -2877 | 2096 |
| PART | 12 | 0 | 0 | 15.00 | 10.29 | 1211.69 | 18977 | -8204 | 2096 |
| PART | 13 | 0 | 0 | 15.00 | 12.48 | 1464.50 | 16618 | -8789 | 2096 |
| PART | 14 | 0 | 0 | 15.00 | 5.55 | 651.42 | 11958 | 2877 | 2051 |
| PART | 15 | 0 | 0 | 15.00 | 10.29 | 1211.69 | 18977 | 8204 | 2051 |
| PART | 16 | 0 | 0 | 15.00 | 12.48 | 1464.50 | 16618 | 8789 | 2051 |
| PART | 90 | 1 | 0 | 9.50 | 12.61 | 940.85 | 14279 | -1479 | 1051 |
| PART | 90 | 2 | 0 | 9.50 | 12.61 | 940.85 | 14279 | 1470 | 1051 |
| PART | 91 | 1 | 0 | 9.00 | 0.71 | 50.55 | 14518 | 8240 | 1226 |
| PART | 91 | 2 | 0 | 9.00 | 0.76 | 53.76 | 15142 | 8240 | 1175 |
| PART | 91 | 3 | 0 | 9.00 | 0.76 | 54.14 | 15766 | 8240 | 1145 |
| PART | 91 | 4 | 0 | 9.00 | 0.79 | 56.60 | 16590 | 8240 | 1112 |
| PART | 91 | 5 | 0 | 9.00 | 0.81 | 57.60 | 17014 | 8240 | 1095 |
| PART | 91 | 1 | 1 | 8.00 | 0.71 | 44.76 | 14518 | -8249 | 1226 |
| PART | 91 | 2 | 1 | 8.00 | 0.76 | 47.78 | 15142 | -8249 | 1175 |
| PART | 91 | 6 | 0 | 9.50 | 1.08 | 80.65 | 15765 | -8249 | 1182 |
| PART | 91 | 7 | 0 | 9.50 | 1.11 | 82.92 | 16588 | -8249 | 1157 |
| PART | 91 | 8 | 0 | 9.50 | 1.12 | 84.15 | 17012 | -8249 | 1119 |
| PART | 92 | 1 | 0 | 9.50 | 0.76 | 57.50 | 15765 | 4420 | 1409 |
| PART | 92 | 2 | 0 | 9.50 | 0.84 | 62.96 | 16589 | 4420 | 1346 |
| PART | 92 | 3 | 0 | 9.50 | 0.91 | 67.85 | 17014 | 4420 | 1298 |
| PART | 18 | 1 | 0 | 9.50 | 4.12 | 307.28 | 11065 | 1940 | 1229 |
| PART | 19 | 1 | 0 | 9.50 | 1.16 | 86.50 | 11690 | 1070 | 994 |
| PART | 19 | 2 | 0 | 9.50 | 2.46 | 183.65 | 11690 | 2580 | 1316 |
| PART | 20 | 1 | 0 | 9.50 | 1.16 | 86.69 | 12515 | 1071 | 992 |
| PART | 20 | 2 | 0 | 9.50 | 2.93 | 218.93 | 12515 | 2677 | 1298 |
| PART | 21 | 1 | 0 | 9.50 | 1.16 | 87.16 | 12940 | 1080 | 985 |
| PART | 21 | 2 | 0 | 9.50 | 3.20 | 239.28 | 12940 | 2795 | 1290 |
| PART | 22 | 1 | 0 | 9.50 | 1.17 | 87.25 | 15565 | 1080 | 984 |
| PART | 22 | 2 | 0 | 9.50 | 3.54 | 264.16 | 15565 | 2928 | 1286 |
| PART | 23 | 1 | 0 | 9.50 | 1.16 | 86.87 | 14190 | 1072 | 990 |
| PART | 23 | 2 | 0 | 9.50 | 3.91 | 291.68 | 14190 | 3044 | 1267 |
| PART | 24 | 1 | 0 | 9.50 | 1.16 | 86.92 | 14815 | 1072 | 990 |
| PART | 24 | 2 | 0 | 9.50 | 4.20 | 313.45 | 14815 | 3176 | 1265 |
| PART | 25 | 1 | 0 | 9.50 | 1.16 | 86.87 | 15440 | 1072 | 990 |
| PART | 25 | 2 | 0 | 9.50 | 5.51 | 411.56 | 15449 | -3112 | 1252 |
| PART | 25 | 4 | 0 | 9.50 | 4.67 | 348.79 | 15440 | 3306 | 1262 |
| PART | 26 | 1 | 0 | 9.50 | 1.16 | 86.92 | 16065 | 1072 | 990 |
| PART | 26 | 2 | 0 | 9.50 | 4.92 | 367.10 | 16065 | 3399 | 1249 |
| PART | 27 | 1 | 0 | 9.50 | 1.16 | 86.87 | 16690 | 1072 | 991 |
| PART | 27 | 2 | 0 | 9.50 | 5.34 | 398.60 | 16690 | 3533 | 1242 |
| PART | 28 | 1 | 0 | 9.50 | 1.04 | 77.57 | 17315 | 1204 | 1044 |
| PART | 28 | 2 | 0 | 9.50 | 6.50 | 484.99 | 17324 | -3425 | 1212 |
| PART | 28 | 4 | 0 | 9.50 | 5.83 | 434.76 | 17315 | 3599 | 1246 |
| TOTAL | | | | | | 14460.98 | 14748 | 620 | 1573 |

Any time, later, that the topology of the part is changed, the user will get a message on the screen that part nos. involved will be deleted.
If, on a finished part, the internal structure is changed, by adding a hole or removing a stiffener trace, the parts involved will be automatically updated without any interference by the user. If the user wants to generate snipes (corner cutouts) at one or more corners of the parts this is done by initially using a SET-command to establish a basic radius.
(SET-CORNER-OUT-RAD 10). Now **10** mm is set as basic radius for corner snipes. When pointing at a corner with the crosshair and using the 2 key on the keyboard when pointing, a corner cutout with radius 20 mm is generated at that corner.
By proceeding in this way parts are generated and stored in assemblies in the database. Weights and center of gravities can be generated for assemblies and printed out in various formats. Also other reports from the database can be generated by report-generator facilities.

The PARTGEN commands include all the AUTOPART commands familiar to the yards using this module presently. This means that all the geometry possibilities in AUTOPART are available in PARTGEN, and so are the macro facilities. This fact will make the transition from AUTOPART to PARTGEN easy and quick for old users.

By using the PARTGEN module for production part generation, the actual part coding, as we know it from ALKON and AUTOPART will in effect disappear, and thus represent a tremendous saving in time required to generate production parts.
A conservative estimate of 3O-50% savings in manhours at the loft for part generation ban be expected.

# CASA: A SYSTEM FOR COMPUTER AIDED SHIP ACCOMMODATION

Piergiacomo Banda
Manager Technical Applications
Italcantieri
Trieste, Italy

Dr. Banda is currently rasponsible for defining strategies of the company in the technical applications field from the hardware and software point of view. He has spent the majority of the last 10 years managing software projects for basic and detailed design of ships.

Dr. Banda holds PhD degrees in naval architecture and in mechanical engineering. He has been appointed to the International Organizing Committee of ICCAS.

Giustiniano Di Filippo
Project Leader
Italcantieri
Trieste, Italy

Dr. Di Filippo is currently responsible for the design and development of a system for the general arrangement plan known as GAP. He previously served as project leader of the CASA system.

Dr. Di Filippo holds a PhD degree in mechanical engineering.

## ABSTRACT

The Computer Aided Ship Accommodation (CASA) system is very advanced in the field of automatic design. CASA has been planned for the production of drawings of high graphic quality, the relevant bill of material, and the preparation of the workship documentation. The system uses interactive graphic techniques to facilitate both the man-machine communication and to increase the throughput and flexibility of the programs.

CASA has three main modules: (1) Description of standards is handled in batch mode. In this case the input concerns standard materials description and general selection rules. These data are stored into the database of the system; drawings and lists are also provided. (2) Description of ship design data. From structural drawings the main data are loaded into the computer for further processing. All the operations of this phase are considerably simplified (thanks to a particular "user-oriented" language) and do not require specific knowledge of EDP. Relevant output drawing will constitute the basic layout of accommodation. (3) Interactive automatic design. From description of construction data and standards with the aid of interactive functions of CASA, "automatic" and "interactive" design are developed. Automatic design, which foresees data processing for each constructive detail, is completely handled in its initial phase in batch mode. Interactive design allows corrections and modifications of data and programs with immediate feedback, thus giving the operator the possibility of a quick and easy communication with the computer.

The problem

Furnishing of naval superstructures includes: localization and -definition of habitable volumes, their sub divisions in cabins, service rooms, rooms for common use etc., definition of materials needed for construc tion of all this and for furnishing of all rooms; pre paration of all drawings and lists necessary for or ders, construction, and fitting up on board. This activity, which is gratifying for a creativity aspect in the phases of design and furnishing definition, be comes extremely boring in the successive phase concerning detailed specification of the thousands of compo nents necessary.

The solution

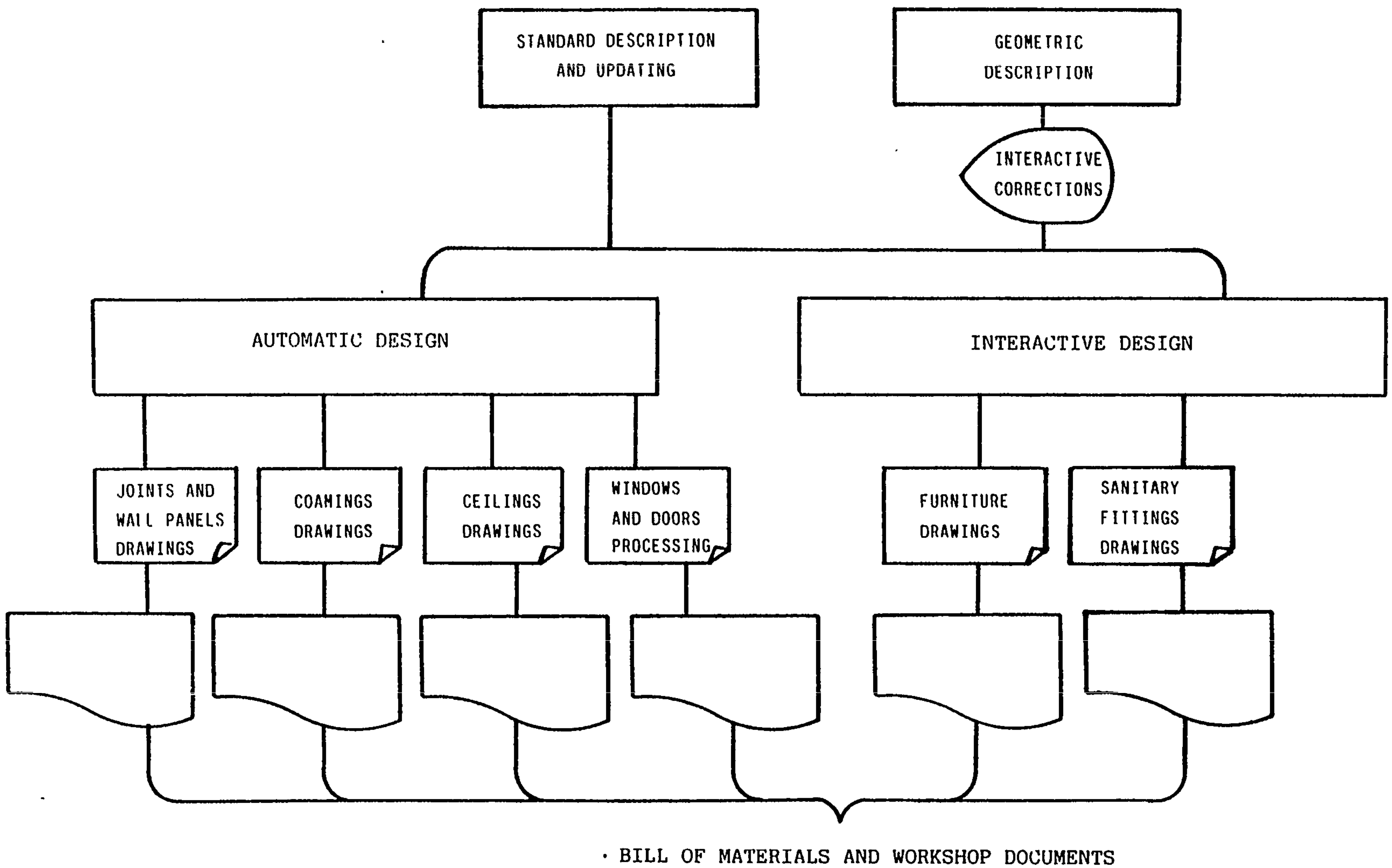
The CASA (Computer Aided Ship Accomodation) without interfering with designer's creativity, and helping instead the designer with ease of execution in his choice among many alternatives, automatically produces all drawings consequent upon design activities, subdivides furnishing elements in elementary components, prepares materials lists and automatically produces all work-shop documents.

CASA SYSTEM

The CASA system is subdivided into three principal modules:

- STANDARDS DESCRIPTION
- GEOMETRIC DESCRIPTION OF SHIP AND AUTOMATIC DESIGN
- DESIGN **IN** THE INTERACTIVE MODE

## CASA SYSTEM GENERAL FLOW



## STANDARD DESCRIPTION

At the basis of any computer data handling there is always a high standardization of material to be handled.

But standardization introduces into design a rigidity factor which, if it is not carefully estimated, may considerably reduce the utility of the software tool.

The CASA management of standards has overcome this obstacle by allowing to insert, cancel and modify the standardized elements by simple draftsmen operations.

The most important furnishing elements to be codified are: doors, walls, ceilings, sidelights, windows, furniture, sanitary fittings, profiles of walls and ceilings, support furrings, coamings, etc.

All standardized materials are completed with a code which foresees on easy identification of the product and of its components from the order to the reception, manifacturing and installation on board.

The data-base of standards stores the codes and data regarding the materials to be used in all ships.

For every new ship the general standards are examined and if necessary integrated or modified.

In the standards data-base are also stored the graphic elements which appear in the drawings such as: beds, tables, chairs etc.

GEOMETRIC DESCRIPTION OF THE SHIP

The first phase of this job consists of description of all geometric and topographic features of all furnishing elements and of all structures which are essential for the successive design work.

Subdivision into decks

The ship's superstructures are subdivided into decks and the relevant data are stored deck by deck.
The elements and structures to be stored are:

- steel walls
- internal furnishing walls
- web frames
- girders
- stiffeners
- pillars
- sidelights and windows
- doors
- reference lines
- blocks subdivision lines

The first result of the work performed is a plan obtained by plotter visualizing all input data.

DECK     .JOB ORDER CODE

.ZONE

```
@ELT,IL DATI
ELTOT7 RLIB72 01/25-12:04:08-(,0)
000001       000    PONT 4343 74 B DECK
000002       000    INPUT
000003       000    ORIGIN R031
000004       000    PARETI L MET 0 10080 12800 PIU08
000005       000    PARETI T MET 10080 12800 -10080 PIU08
000006       000    PARETI L MET 12800 -10080 0 MEN08
000007       000    PARETI T MET -10080 0 10080 MEN08
000008       000    PARETI L MET R041 5040 R047 PIU06 S
000009       000    PARETI L MET R031 5040 R032 000700 PIU06
000010       000    PARETI T MET 5040 R039 -5040 MEN06
000011       000    PARETI L MET R033 000050 -5040 R031 MEN06
000012       000    PARETI T MET -1680 R036 3480 PIU06
000013       000    PARETI T MET -1680 R035 -2750 MEN06
000014       000    PARETI L MET R035 -2750 R035 000200 PIU06
000015       000    PARETI T MET -2750 R035 000200 -4640 MEN06
000016       000    PARETI L MET R035 000200 -4640 R035 000075 MEN06
000017       000    PARETI L MET R035 000200 -4240 R037 MEN06
000018       000    PARETI T MET -5040 R037 -3440 MEN06
000019       000    PARETI L MET R037 -3440 R038 MEN06
000020       000    PARETI T MET -3440 R038 -5040 MEN06
000021       000    PARETI T MET 5040 R035 3480 PIU06
000022       000    PARETI L MET R035 3480 R037 PIU06
000023       000    PARETI T MET 3480 R037 5040 PIU06
000024       000    PARETI L MET R035 -1680 R039 MEN06
000025       000    PARETI L MET R034 000200 5040 R039 PIU06
000026       000    PARETI L MET R034 000350 -5040 R039 MEN06
000027       000    PARETI L MET R038 -3840 R039 PIU06
000028       000    PARETI T MET 200 R039 000260 -200 PIU08
000029       000    PARETI L MET R039 -200 R039 000260 -200 MEN08
000030       000    PARETI L MET R039 200 R039 000260 PIU08
000031       000    PARETI L ARP 400 9600 12300 S
000032       000    PARETI T ARP 5100 S
000033       000    PARETI L ARP 7700 S
000034       000    PARETI T ARP 9600 7700 -9600
000035       000    PARETI L ARP 7700 4800 12300 S
000036       000    PARETI T ARP -4800
000037       000    PARETI L ARP 7700 1600 12300 S
000038       000    PARETI T ARP 9600 9200 6100 S
000039       000    PARETI L ARP 7700 S
000040       000    PARETI L ARP 7700 8100 9200 S
000041       000    PARETI L ARP 7700 7600 9200 S
000042       000    PARETI L ARP 7700 3300 9200 S
000043       000    PARETI T ARP 4800 S
000044       000    PARETI L ARP 7700 100 9200
000045       000    PARETI T ARP 1600
000046       000    PARETI L ARP 0 6100 7700 S
000047       000    PARETI T ARP 6100 400 9600
000048       000    PARETI T ARP 5100 1500 6100 S
000049       000    PARETI T ARP 6100 4400 9600 S
000050       000    PARETI T ARP -9600 400 -7600
000051       000    PARETI T ARP -6100 300 -6900
000052       000    PARETI T ARP -7600 1800 -6100
000053       000    PARETI L ARP 300 -7600 1800
000054       000    PARETI L ARP R031 5100 R033
000055       000    PARETI L ARR 0 -5100 1700
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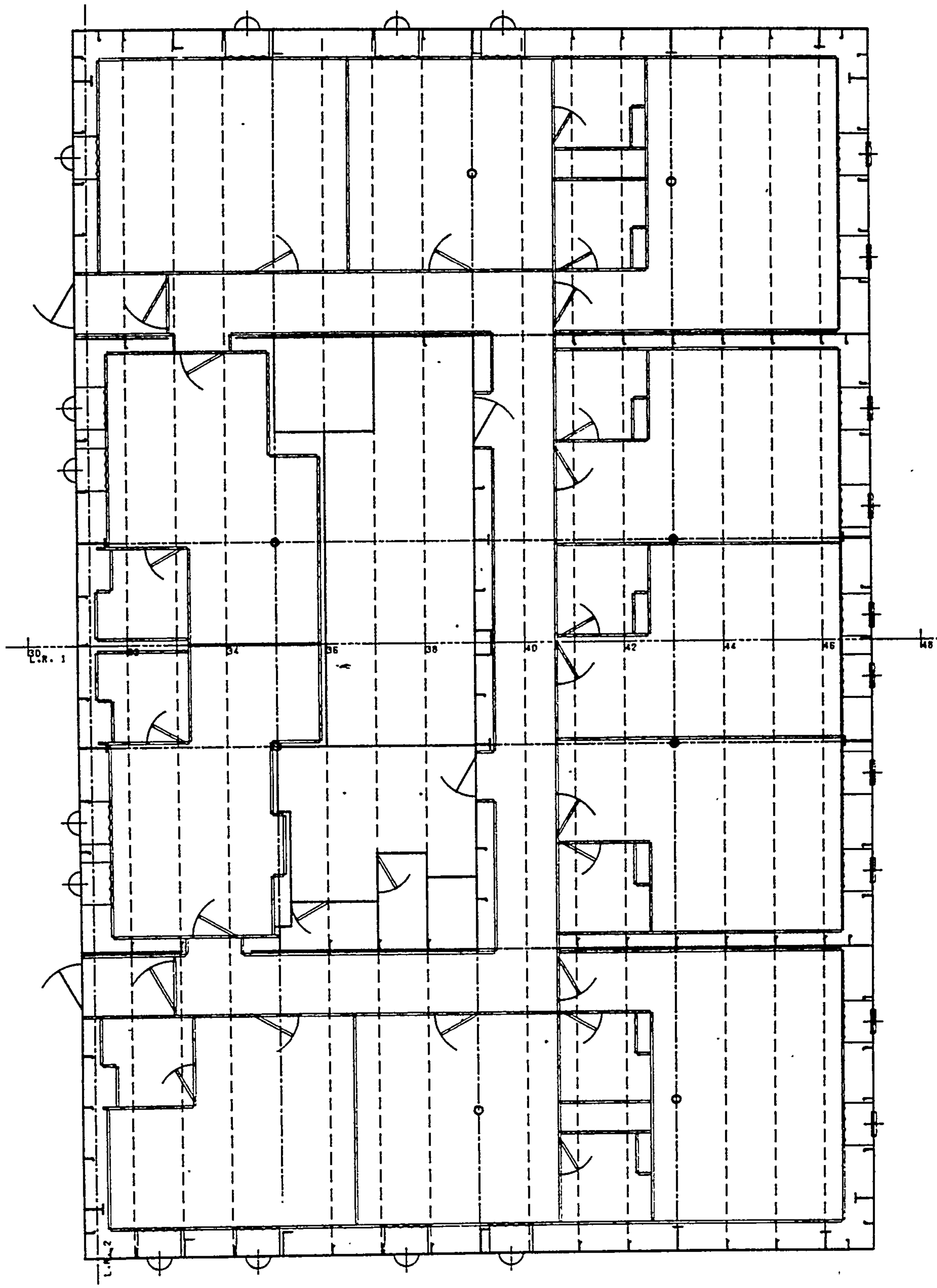
ELEMENT NAME

ELEMENT TYPE

ELEMENT'S CO-ORDINATES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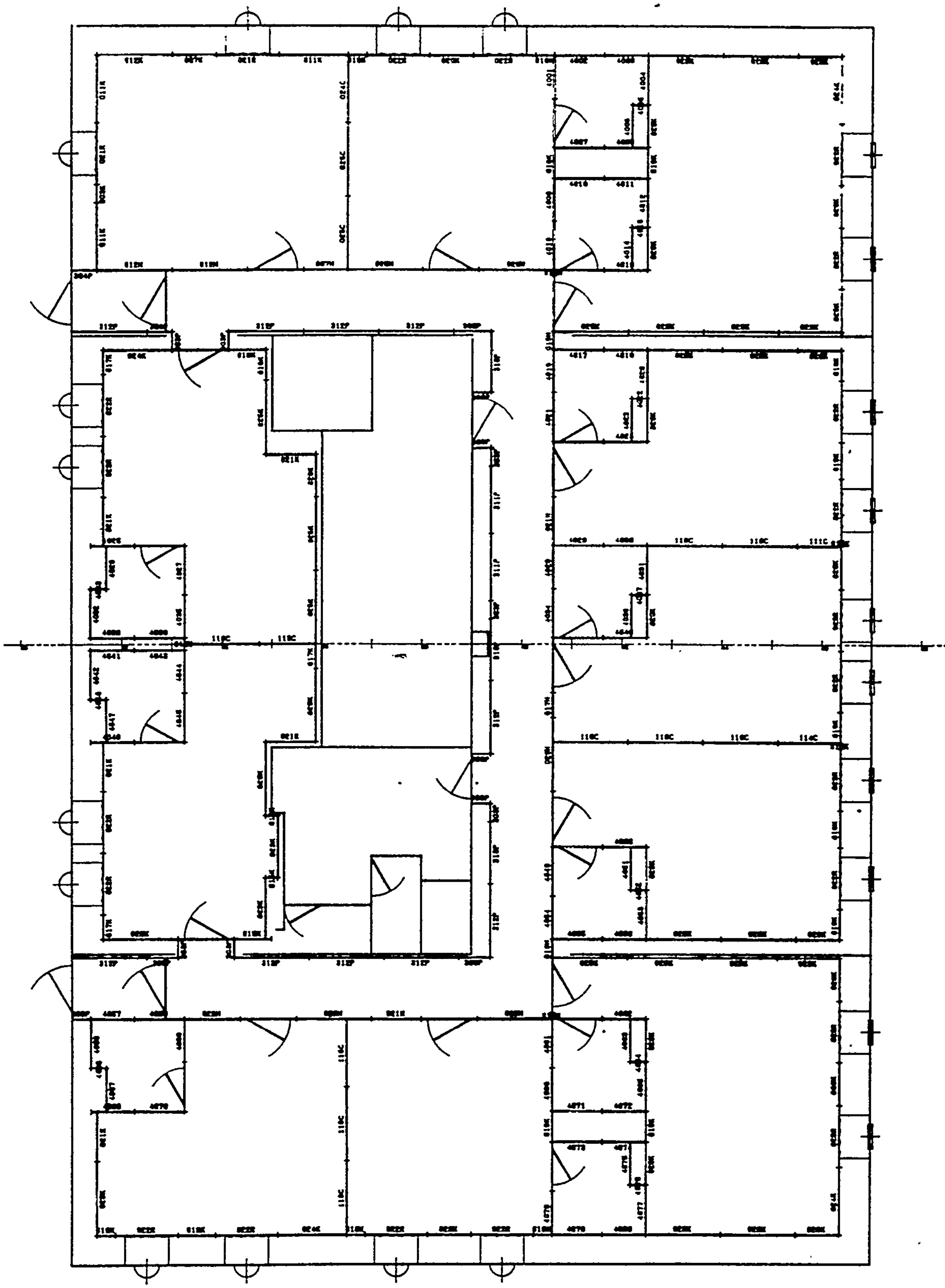
| | |
|---|---|
| Interactive correction of data | In this phase it is already possible to intervene in the interactive mode; in fact, using a graphic interactive screen the basic data(as bulkheads, sidelights , or doors) can be simply and immediately corrected. |
| Menii , | In order to free the operator from the need to acquire knowledge of the computer operating **system, a com**mand table (MENU') is visualized on the screen to facilitate all operations of communication with the computer. |
| Ease of communication with the computer | By setting the screen cross-hair, on one of the menu rectangles, the program is set to perform all required operations. |
| Data safety | In the working phases the system, in order to avoid unintentional damages of data by the user, operates on temporary files which are created each **time,** while the ship file is used only in the reading and up-dating phases. |
| Output facilities | By utilization of the command table, it is also possible to address the stored data to any external support: graphics screens, pen-plotters and printer plotters. |

| | |
|---|---|
| <u>AUTOMATIC DESIGN</u> | After all data are stored and checked, the successive procedures of automatic design are utilized. |
| Procedure for panels, bulkheads, and joints | CASA automatically subdivides into panels, with mod; lar criteria, all internal furnishing walls.<br>According to the colour and the type of wall they belong to, it classifies and marks all panels, classifies and marks all joints; it produces according to specific criteria of scrap reduction, the cutting schemes for panelling, the plan for joints and all materials lists necessary for order and installation of relevant **materials.** |



Wall panels nesting booklet

These lists are obtained by an automatic procedure starting from the data relevant the decks to be processed and materials to be employed in the construction of the panels.
The following pages show the scheme to be used in the workshop for cutting panels, the scrap of **mate-**rials, the total quantity of the panels to be made per lot and the total average scrap.

| ITALCANTIERI<br>**TEC/ARR** | SCHEMA TAGLIO PANNELLI PARETI | WALL PANELS NESTING<br>COSTR 4343 LOTTO N. | MODIFICHE | N° FOGLIO |
|---|---|---|---|---|
| COMPILATO<br>XII | STAB. MO — CAP — AUT 0810 — DATA 03/02/78 | ZONA 74<br>DIS. 3/057 | INDICE · NOME · DATA | 2 |

| | |
|---|---|
| PANNELLI SERIE N. 1 RIVESTIMENTO | PANNELLI PREPLACCATI · LARGHEZZA : 1170 --- ALTEZZA : 2160// TOTALE PEZZI DELLA SERIE : 6 |

SCHEMA N. 1 ! PANNELLI NORMALI ETERNAVE — INNER PANELS (MATERIALS) — SCRAPS

| | | | | |
|---|---|---|---|---|
| PLACCATURA : | LARGH ! 1170 | PANEL WIDTH | SFRIDO | 0 |
| LAMIER LPR104 | MARCA ! 612K | STANDARD PIECE-NUMBER | PEZZI | 1 |

PIECES

SCHEMA N. 2 ! PANNELLI NORMALI ETERNAVE

| | | | |
|---|---|---|---|
| PLACCATURA : | LARGH ! 1070 | SFRIDO | 100 |
| LAMIER LPR104 | MARCA ! 611K | PEZZI | 3 |

COVERING MATERIAL

SCHEMA N. 3 ! PANNELLI NORMALI ETERNAVE

| | | | |
|---|---|---|---|
| PLACCATURA : | LARGH ! 670 ! 270 | SFRIDO | 230 |
| LAMIER LPR104 | MARCA ! 607K ! 603K | PEZZI | 1 |

Mod. 994.1153.C1 - M.Scotti 264177

**Material withdrawal notes**

The withdrawal notes are automatically obtained. They contain the information to withdraw, the material necessary for the construction of the wall panels.

| ITALCANTIERI TEC/ARR | SCHEMA TAGLIO PANNELLI PARETI | | | COSTR. 4343 | LOTTO N. 1 | MODIFICHE | | | N.° FOGLIO |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | INDICE | NOME | DATA | |
| COMPILATO XII | STAB. 110 | CAP. ART. 08 10 | DATA 03/02/78 | ZONA 74 DIS. 3/057 | | | | | 28 |

PANEL QUANTITY PER LOT

TOTALE PANNELLI DELLE VARIE MARCHE E LARGHEZZE DA ESEGUIRE PER QUESTO LOTTO 250

SFRIDO MEDIO DOVUTO A TAGLI SEGA ED A RITAGLI NON UTILIZZABILI 10.306%

AVERAGE SCRAP

| ITALCANTIERI TEC/ARR | PANNELLI DI TIPO OMOGENEO | COSTR. 4343 | LOTTO N. 1 | MODIFICHE: INDICE / NOME / DATA | N.° FOGLIO |
|---|---|---|---|---|---|
| COMPILATO: XH | STAB. MO — CAP 08 ART 10 — DATA 03/02/78 | ZONA 74 — DIS. 3/057 | | | 1 |

JOB ORDER CODE

MATERIAL WITHDRAWAL NOTES

```
STA! COSTR !CAP/ART!VOCE!LOTTO!      BUONI PRELIEVO MATERIALI PER ESECUZIONE        ! PAG
---!-------!-------!----!-----!      PANNELLI PARETI DELLA SERIE N.   1             !-----
MO!   4343!  0010 !    !    1!                                                     !    1

   !       !CAP    !    !TIP!NO.BUONO!        !C!U!N. ! COMM.  ! !
STA! COSTR !  -ART!VOCE!MOV!PRELIEVO! CODICE !A!M!PEZ! PREL.  ! !PANNELLO DI ETERNAVE      L=1170 MM.-H=2160 MM.
---!-------!-------!----!---!--------!--------!-!-!---!--------! !
MO!   4343!  0010 !    ! 72! 001001!        !4!1!  6!        ! !

   !       !CAP    !    !TIP!NO.BUONO!        !C!U!N. ! COMM.  ! !
STA! COSTR !  -ART!VOCE!MOV!PRELIEVO! CODICE !A!M!PEZ! PREL.  ! !CONTROPLACCATURA IN LAMIER L=1170 MM.-H=2160 MM.
---!-------!-------!----!---!--------!--------!-!-!---!--------! !
MO!   4343!  0010 !    ! 72! 001002!        !4!1!  6!        ! !

   !       !CAP    !    !TIP!NO.BUONO!        !C!U!N. ! COMM.  ! !
STA! COSTR !  -ART!VOCE!MOV!PRELIEVO! CODICE !A!M!PEZ! PREL.  ! !LAMINATO PLASTICO LPR104   L=1170 MM.-H=2160 MM.
---!-------!-------!----!---!--------!--------!-!-!---!--------! !
MO!   4343!  0010 !    ! 72! 001003!        !4!1!  6!        ! !
```

MATERIAL   SIZE

SHIPYARD NAME

MATERIAL WITHDRAWAL NOTE NUMBER

Mod. 94.1153.01 - Mosen. 26/3/74

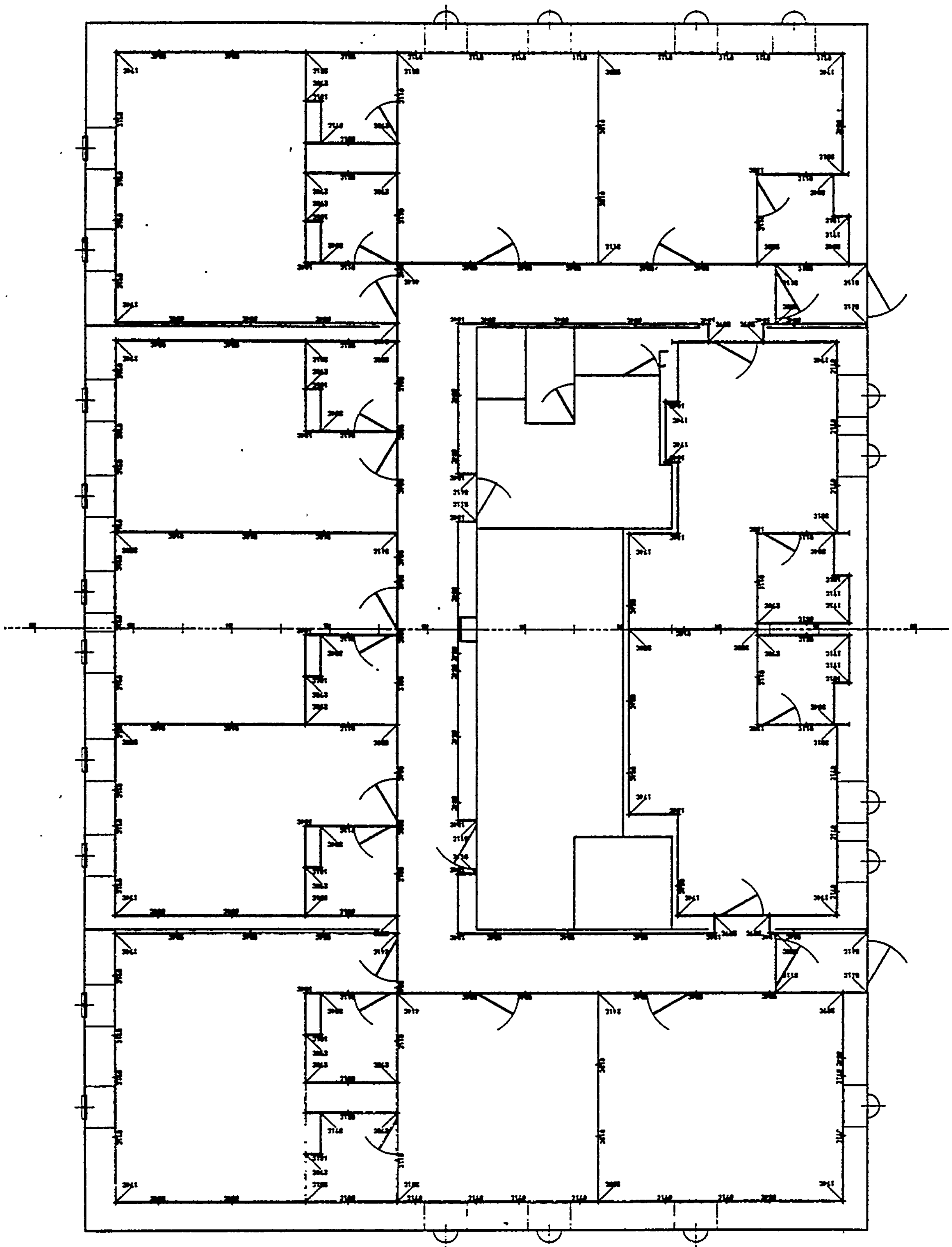
| ITALCANTIERI TEC/ARR | CONSUNTIVO FABBISOGNO PANNELLI PARETI | COSTR. 4343 | LOTTO N. 1 | MODIFICHE: INDICE / NOME / DATA | N° FOGLIO |
|---|---|---|---|---|---|
| COMPILATO: XII | STAB. MO — CAP. ART. 08 10 — DATA 03/02/78 | ZONA 74 — DIS. 3/057 | | | 1/3 |

ELEMENT NAME     KIND OF WALL     SIZE     PIECES

| | | | |
|---|---|---|---|
| PANNELLI DI ETERNAVE | PER PARETI NORMALI.................. | 1170X2160 | PEZZI 87 |
| PANNELLI DI ETERNAVE | PER PARETI DI CLASSE B ............... | 1170X2160 | PEZZI 33 |
| PANNELLI DI LAMIER PER CONTROPLACCATURA PANNELLI NORMALI......... | | 1170X2160 | PEZZI 72 |
| PANNELLI DI LAMIER PER CONTROPLACCATURA PANNELLI CLASSE B ....... | | 1170X2160 | PEZZI 21 |
| PANNELLI DI ETERNAVE | PER PARETI NORMALI LOC.IG.PREALL....... | 770X2160 | PEZZI 66 |
| PANNELLI DI ETERNAVE | PER PARETI DI CLASSE B L.IG.PREALL..... | 770X2160 | PEZZI 8 |
| PANNELLI DI LAMIER PER CONTROPLACCATURA PANNELLI L.IG.PREALL..... | | 770X2160 | PEZZI 37 |

Summary of material requisition order

This output shows the material summary of the wall-panels relevant to a lot.



| ITALCANTIERI TEC/ARR | LISTINTA QUANTITATIVI GIUNTI E RELATIVI COMPONENTI | | | COSTR. 4343 | LOTTO N. 1 | MODIFICHE | | | N.° FOGLIO |
|---|---|---|---|---|---|---|---|---|---|
| COMPILATO: XP | TAB. PO | CAP. 08 | ART. 10 | DATA 03/02/78 | ZONA 74 — DIS. 3/051 | INDICE | NOME | DATA | 11 |

STANDARD PIECE-NUMBER

COLOUR

SERIE N. 21 - MARCA 236C MARCA COMPLETA PA*236JC - COLORE COME LPR358 - COMPLESSI DA ESEGUIRE 4

QUANTITY

| COMPONENTI: | PEZZI PER COMPLESSO: | N. TOTALE COMPONENTI: |
|---|---|---|
| PROFILO MARCA A009 | 1 | 4 |
| PROFILO MARCA A138 | 1 | 4 |
| PROFILO MARCA A070 | 1 | 4 |
| VITI AB 4.2X32 UNI 6956 | 7 | 28 |
| VITI NE 925830 4.5X20 | 26 | 104 |
| TRECCIA AMIANTO 25X10 H=2180 | 1 | 4 |
| TRECCIA AMIANTO 25X3 H=2180 | 1 | 4 |

QUANTITY

COMPONENTS

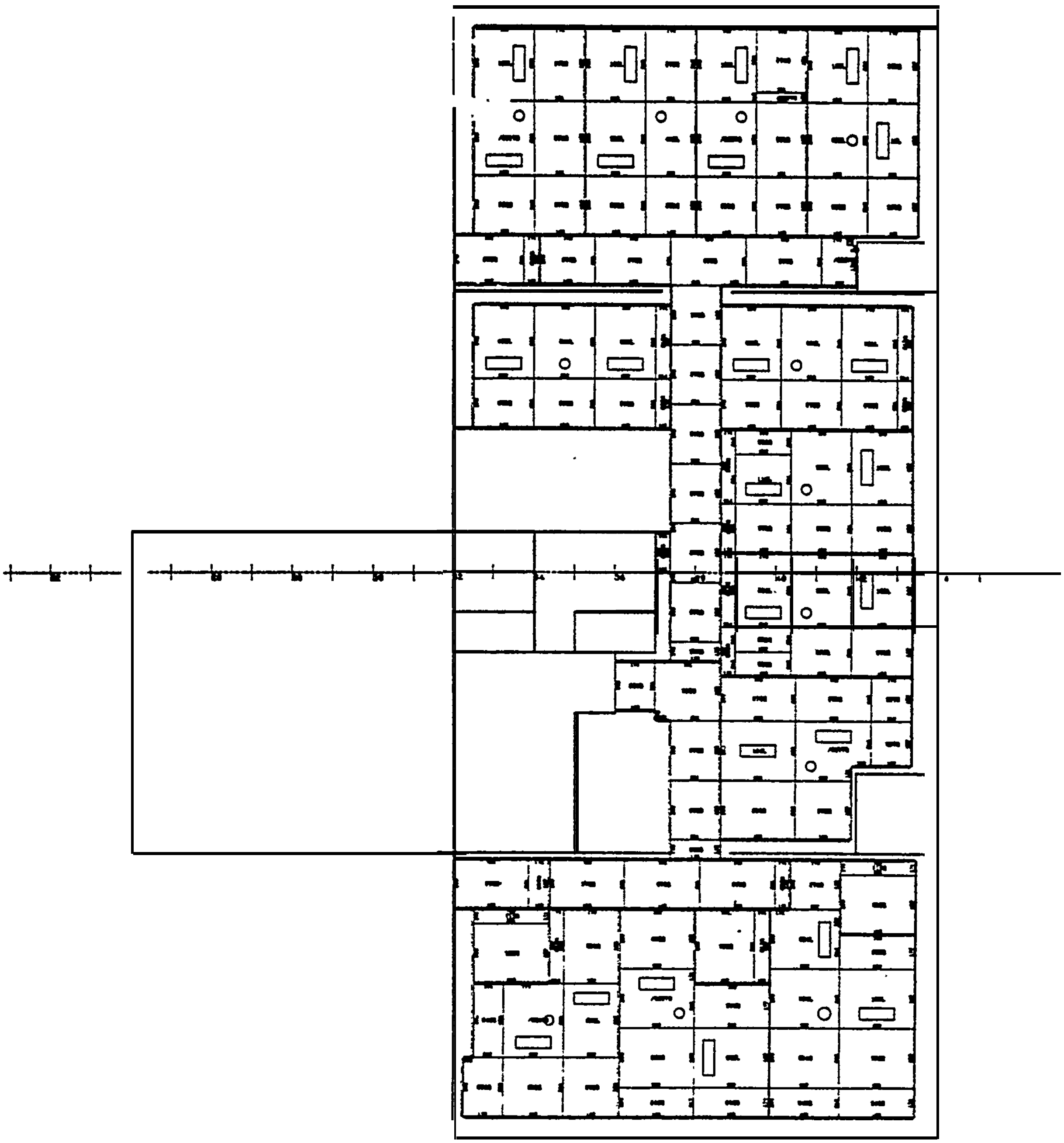
SERIE N. 22 - MARCA 031C MARCA COMPLETA PA*031JC - COLORE COME LPR358 - COMPLESSI DA ESEGUIRE 4

| COMPONENTI: | PEZZI PER COMPLESSO: | N. TOTALE COMPONENTI: |
|---|---|---|
| PROFILO MARCA A009 | 1 | 4 |
| PROFILO MARCA A030 | 1 | 4 |
| GIRANDOLE TIPO 461 | 1 | 4 |
| VITI AB 4.2X16 UNI 6956 | 6 | 24 |
| VITI AB 4.2X32 UNI 6956 | 1 | 4 |
| TRECCIA AMIANTO 25X10 H=2180 | 1 | 4 |
| TRECCIA AMIANTO 25X3 H=2180 | 1 | 4 |

Procedure for ceiling panels

CASA, by working cabin by cabin, subdivides the ceiling into panels following a criterion aiming principally at reducing the junction profiles length and the number of non rectangular panels; the research of the best solution is automatic but it is always possible to introduce, by screen, preferential subdivision Lines and the system automatically fits the subdivision to the imposed lines.
After subdivision, individuation, and marking of panels, storing and marking is performed for profiles and support structural elements of the panels and of ceiling Lamps.
As automatic outputs we have:

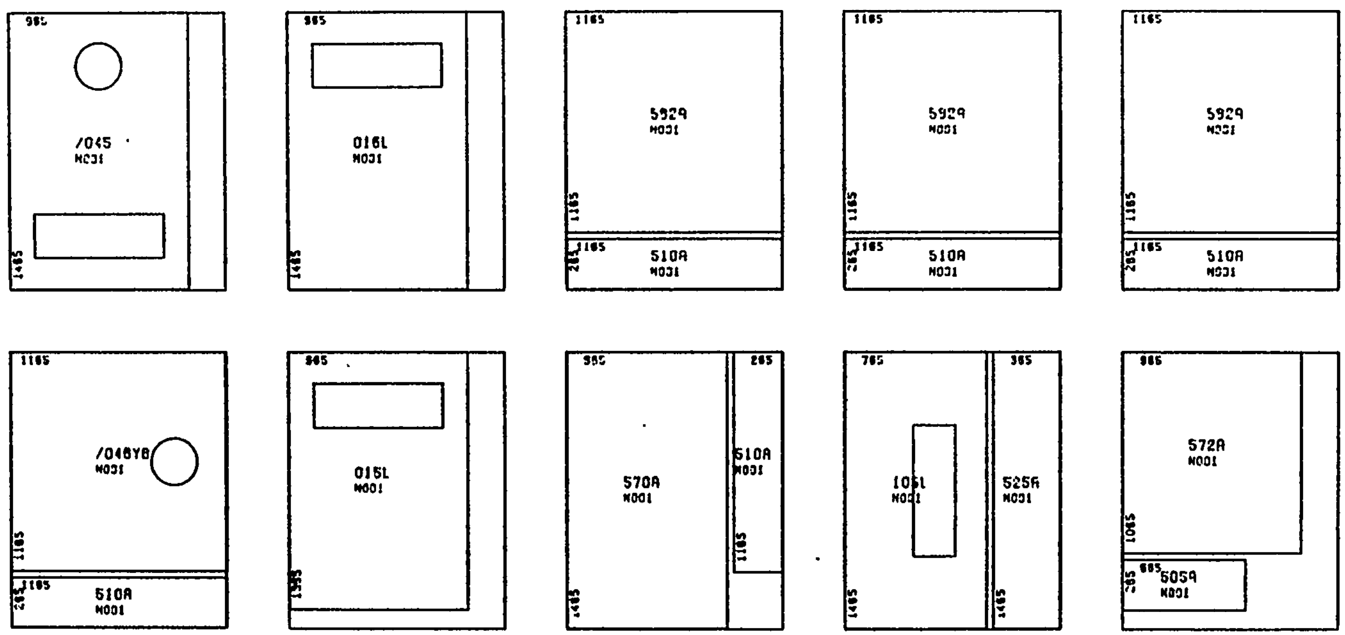
- plan for ceiling panelling
- plan for furrings
- panels nesting
- material lists for procurement, construction, and installation of materials on board.



| ITALCANTIERI - TEC/ARR | | | | DIS 837270061 | COSTR. 4363 |
|---|---|---|---|---|---|
| DATA | NOME | FIRMA | SCALA | TITOLO | ZONA 76 |
| | | | 1:20 | SCHEMI TAGLIO PER L'ESECUZIONE DEI PANNELLI PER SOFFITTI | FOGLIO NO. 4 |

CEILINGS PANELS NESTING

PANNELLI CLASSE N DIS. TI 727340 - TI 727440 ESECUZIONE A
ANIMA IN PANNELLO AD IMPASTO ESENTE DA AMIANTO SP. 9.6
LAMINATO PLASTICO FACCIA IN VISTA COLORE LPRO23 TIPO N SP. 1 NE 214010
CONTROPLACCATURA LAMINATO FENOLICO TIPO N SP. 1 NE 216010



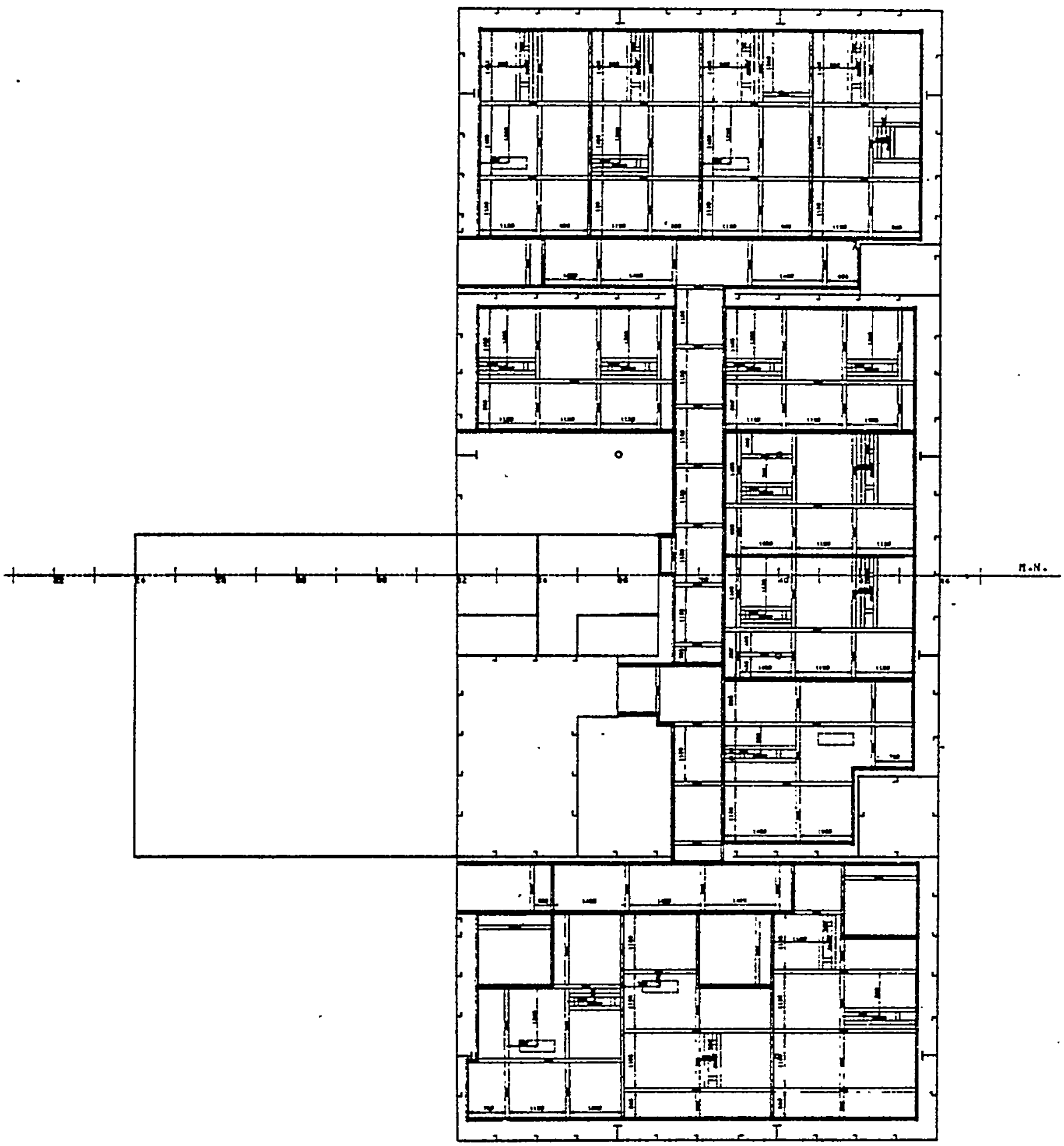
| ITALCANTIERI TEC/ARR | DISTINTA PANNELLI PER SOFFITTI<br>CEILINGS PANELS LIST | | | COSTR. 4363 JOB ORDER CODE | LOTTO N. 2 | MODIFICHE | | | N.° FOGLIO |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | INDICE | NOME | DATA | 1 |
| COMPILATO: DE PAG | STAB. MU | CAP. 08 | ART. 11 | DATA 22/11/78 | ZONA 72<br>DIS. B37270061 | | | | |

PIECE NUMBER

| MARCA | PEZZI | MARCA | PEZZI | MARCA | PEZZI | MARCA | PEZZI |
|---|---|---|---|---|---|---|---|
| 585A | 2 | 123L | 2 | /001YB | 1 | 025L | 7 |
| /006YB | 1 | /002YB | 1 | 584B | 1 | 583A | 2 |
| 121L | 1 | /004YB | 1 | 580B | 1 | 576B | 4 |
| 576A | 7 | /005YB | 1 | 582A | 2 | 575B | 2 |
| 574B | 1 | 574A | 1 | 569A | 1 | 573A | 2 |
| 573B | 4 | 563A | 4 | 562B | 1 | 572A | 1 |
| 572B | 1 | 567A | 2 | 561A | 1 | 571A | 1 |
| 560A | 1 | 565A | 1 | 552A | 1 | 558B | 1 |
| 544A | 1 | 536A | 1 | 170L | 1 | 543A | 1 |
| 556A | 1 | 541A | 2 | 548A | 2 | 522A | 1 |
| 530A | 1 | 513A | 1 | 512B | 1 | 520B | 3 |
| 520A | 1 | 510A | 2 | 508A | 1 | 508B | 1 |
| 507A | 1 | /003YB | 1 | 504A | 1 | 501B | 1 |
| /007YB | 1 | /008YB | 1 | /009YB | 1 | /010YD | 1 |
| /011YB | 1 | /012YB | 1 | | | | |

NUMBER

Mod. 74 1153.01 - Mozzini 26.77



| ITALCANTIERI TEC/ARR | DISTINTA PROFILI PER SOFFITTI | | | COSTR. 63 | LOTTO N. A | MODIFICHE INDICE / NOME / DATA | N.° FOGLIO 1 |
|---|---|---|---|---|---|---|---|
| COMPILATO: FURLAN | STAB. MO | CAP. 08 ART. 11 | DATA 22/11/78 | ZONA 72 DIS. B37270061 | | | |

ELENCO PROFILI PER IMBONAGGI — FURRING PROFILES LIST

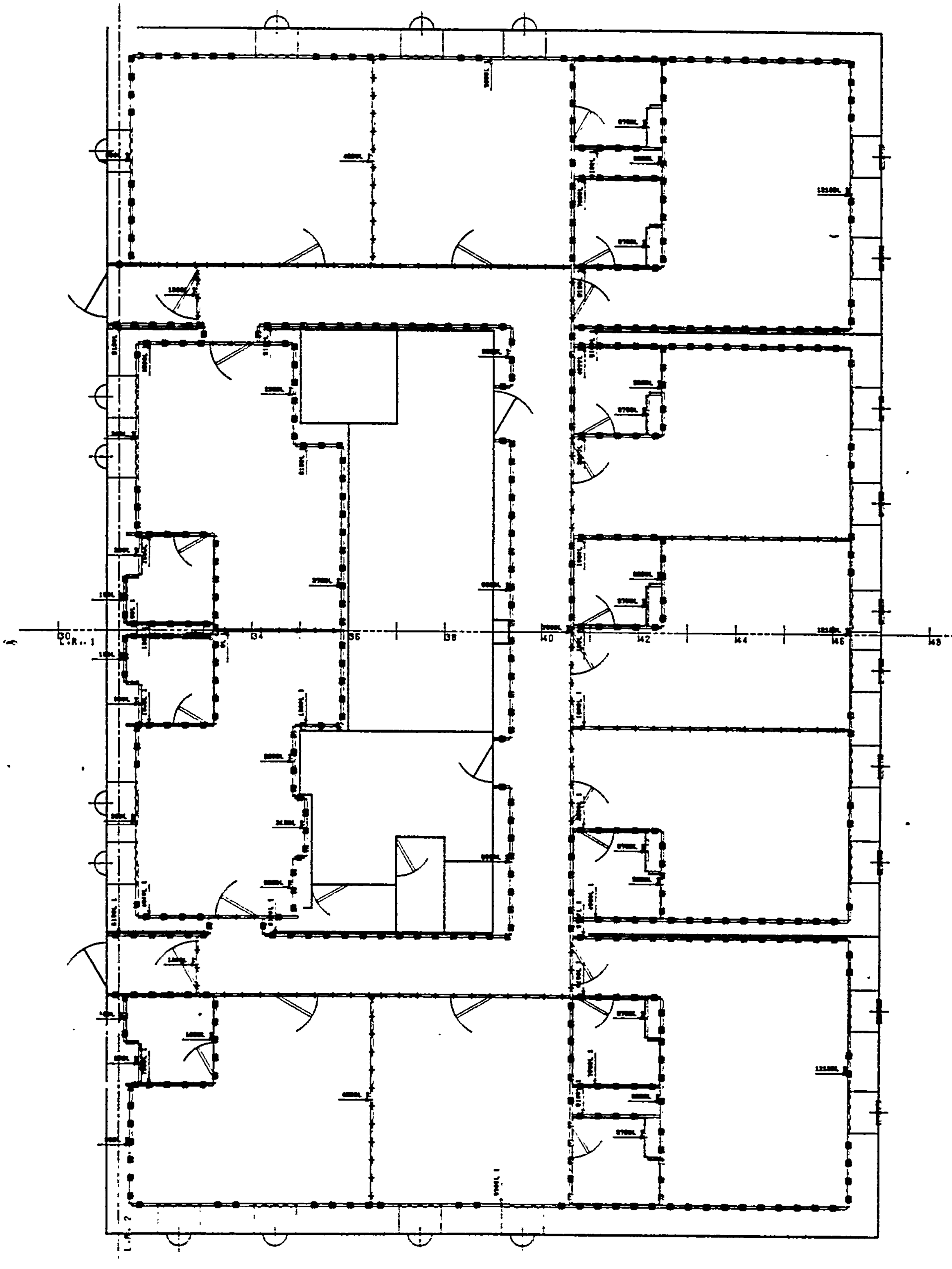
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 522 | PEZZI | 3 | LUNGHEZZA | 210 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 526 | PEZZI | 1 | LUNGHEZZA | 610 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 527 | PEZZI | 8 | LUNGHEZZA | 710 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 528 | PEZZI | 5 | LUNGHEZZA | 810 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 529 | PEZZI | 26 | LUNGHEZZA | 910 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 530 | PEZZI | 2 | LUNGHEZZA | 1010 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 531 | PEZZI | 15 | LUNGHEZZA | 1110 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 532 | PEZZI | 2 | LUNGHEZZA | 1210 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 533 | PEZZI | 2 | LUNGHEZZA | 1310 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 534 | PEZZI | 9 | LUNGHEZZA | 1410 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 536 | PEZZI | 1 | LUNGHEZZA | 1610 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 541 | PEZZI | 1 | LUNGHEZZA | 2110 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 546 | PEZZI | 1 | LUNGHEZZA | 2610 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 547 | PEZZI | 1 | LUNGHEZZA | 2710 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 552 | PEZZI | 1 | LUNGHEZZA | 3210 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 554 | PEZZI | 2 | LUNGHEZZA | 3410 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 558 | PEZZI | 1 | LUNGHEZZA | 3810 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 560 | PEZZI | 1 | LUNGHEZZA | 4010 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 566 | PEZZI | 1 | LUNGHEZZA | 4610 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 568 | PEZZI | 1 | LUNGHEZZA | 4810 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 570 | PEZZI | 2 | LUNGHEZZA | 5010 |
| NI 724550 | IMBONAGGIO FINITO PER SOFFITTI TIPO | 572 | PEZZI | 1 | LUNGHEZZA | 5210 |
| | | | | QUANTITY | | SIZE |

ELENCO PROFILI PER IMBONAGGI — ARCHITRAVI — BULKHEADS UPPER PROFILES LIST

PROFILO SPECIALE SAGOMATO A FREDDO TIPO 701 LUNGH. 6000 - PEZZI 5
PROFILO SPECIALE SAGOMATO A FREDDO TIPO 702 LUNGH. 6000 - PEZZI 9
NI 724550 CAVALLETTO TIPO 431 - PEZZI 174

Mod. 94 / 33.01 - Milano 20...77

| | |
|---|---|
| Procedure for coamings | On the basis of data regarding bulkheads, the type of room concerned, and height of the utilized floor foundation,the various types of profiles necessary for panels support are identified; after being identified, they are drawn with a symbol which is different for each type of profile.<br>The produced plan reports also the profiles dimensions to the next reference line.<br>As for the all other outfitting materials also with this procedure all materials lists are automatically produced. |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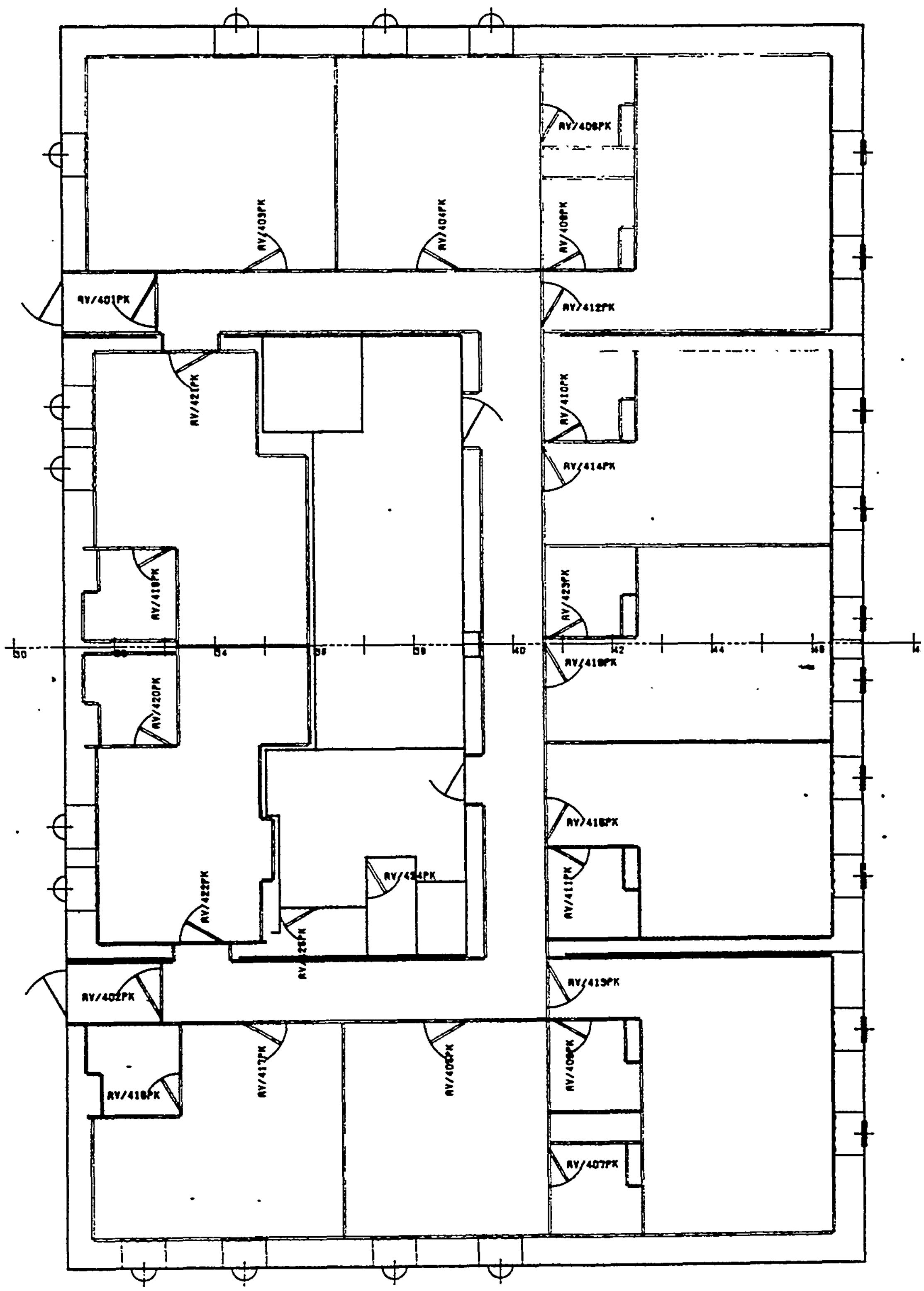
**Procedures for doors, sidelights, and windows**

Processing of previously stored data produces dimensioned and marked plans regarding doors, sidelights and windows and all relevant material lists.



INTERACTIVE DESIGN MODE

In the procedures in which, owing to the fact that the graphic elements to be handled are complex and unforseeable, it is essential to have the availability of the shapes, dimensions and obstacles for a correct storing. For that a graphic-interactive working mode has been adopted.
As hardware support a TEKTRONIX screen, with refresh buffer, was chosen and connected to the Main Computer.
The principal interactive design procedures are those regarding:

- Furniture
- Sanitary fittings
- Ceiling lamps and anemostats

Procedure for forniture

Differently from other procedures where the deck is the working unit, here the work is performed cabin by cabin in order to increase the execution speed by reducing the graphic elements down to the essential.

* Ease of use

In order.to help the operator, it was decided to standardize, besides all pieces of furniture which may interest naval furnishing, also all possible furnishing combinations for each type of cabin.
In this way when the operator retrives the cabin on the screen, all the pieces of furniture which can be there inserted are automatically connected to the cabin's code; they appear one after the other on the screen in the most rational order for the furnishing sequence.

Ease of movements

The graphic elements, which can be connected by a characteristic point at the cross-hair, may be moved on the whole screen and rotated by any angle until they find their most suitable position.

Furnishing for symmetrical or translated cabins

In the case that very often happens in the naval field in which cabins are involved having a perimeter symmetrical or translated with reference to other cabins already furnished, by simple commands it is

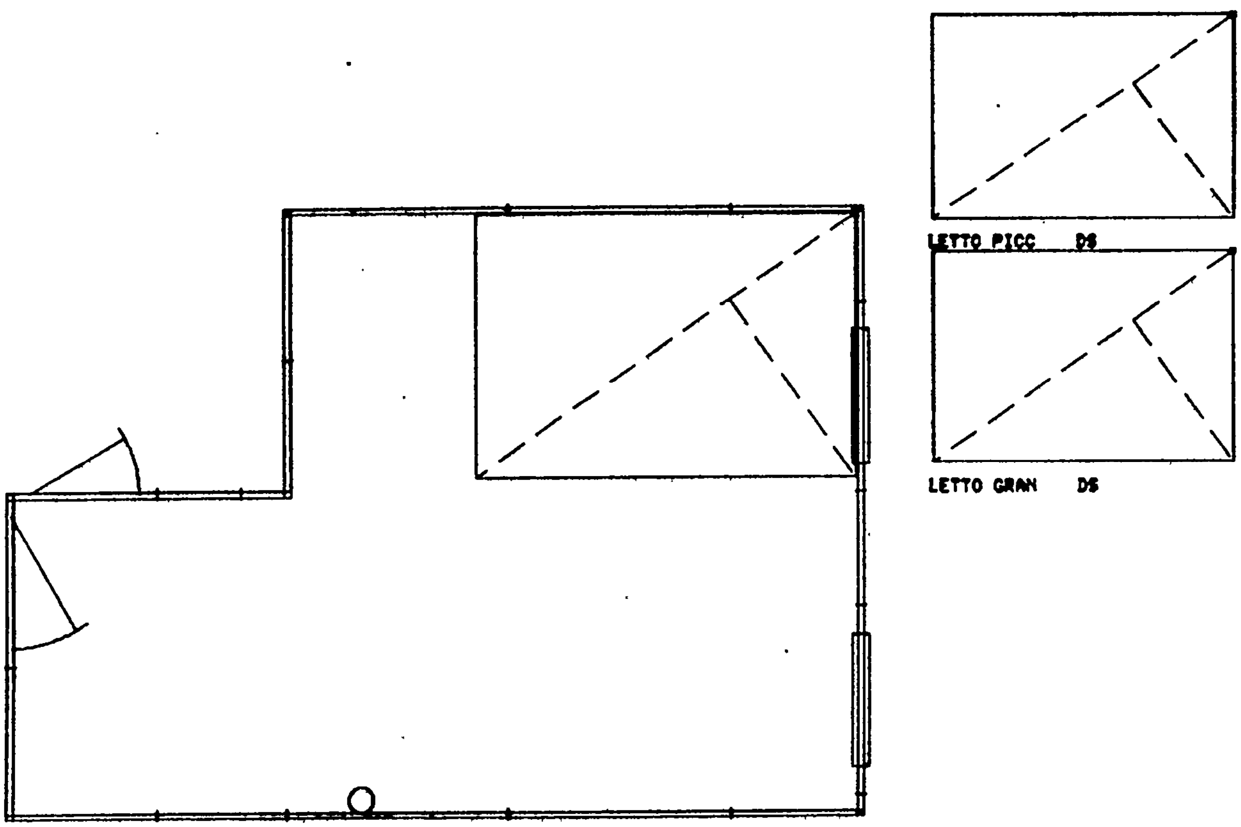
possible to reverse or translate the existing furniture disposition and avoid the tedious repetition of the work; in this way it is possible to furnish the whole ship deck in a very short time.

**Design speed**

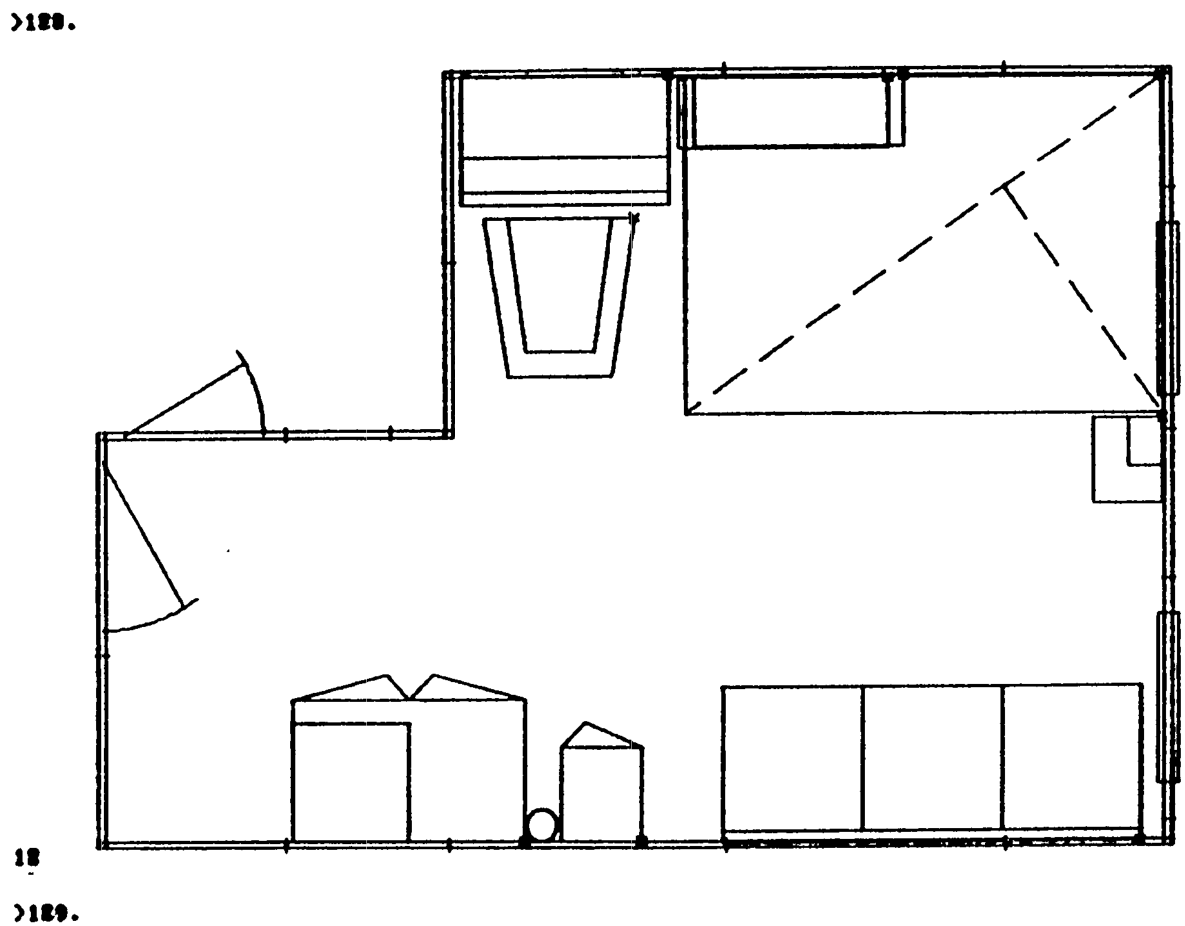
After all cabins are furnished, the system produces, besides the plans in the requested scale, all materials list necessary for construction and assembling of furniture on board.

**Procedure for sanitary fittings**

By a procedure similar to that already examined for furniture, sanitary fittings with all accessories are also positioned **by** screen in the sanitary rooms and also here it is possible to obtain very easily all the drawings and the material lists.




CABINA [illegible]



>128.
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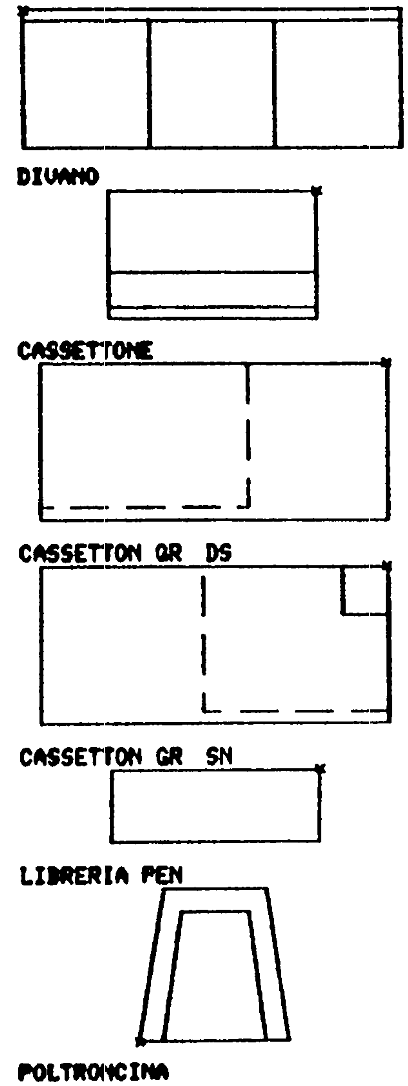
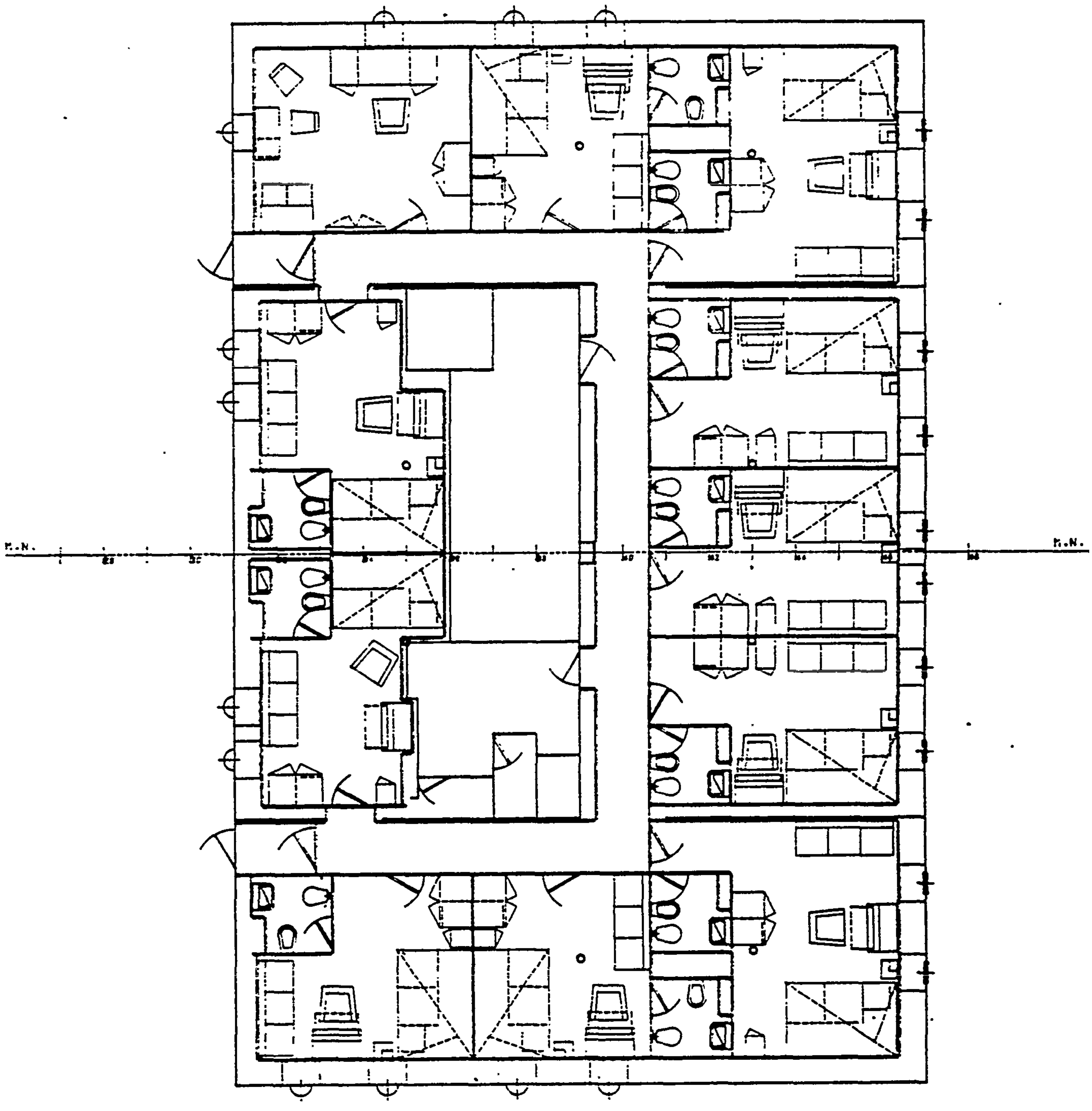


DIVANO
CASSETTONE
CASSETTON GR DS
CASSETTON GR SN
LIBRERIA PEN
POLTRONCINA


CABINA 3005



FURNITURE LIST OF A ROOM

LISTA MOBILI VANO H009 DEST. C01C

COSTR 4343 JOB ORDER CODE

LOTTO N.

ZONA 74

DIS. DIS/01 PALLET

STAB. 10 | 01 | 02 | DATA 1/2/78

| TIPO | COLORE | CODICE OTS | MARC... ZZO |
|---|---|---|---|
| FURNITURE TYPE | COLOUR | MATERIAL CODE | PIECE NUMBER |
| L. TTO PICC DS | TANGANICA WALLNUT | 7311110000N 00100X | JE/ ...LE |
| T..VOLO NOTTE SN | TANGANICA WALLNUT | 7331180000X 08710A | JE/ ... TV |
| C..SSETTONE | TANGANICA WALLNUT | 7337100000H 10750T | JE/ ...CR |
| A. ..ADIO GUAR DS | TANGANICA WALLNUT | 7321110000S 011800 | JE/ ... AR |
| STIPETTO DS | TANGANICA WALLNUT | 7325110000C 05500B | JE/ ... R |
| DIVANO | REX N. 1121 BROWN | 7357110000H 06030H | JE/ ...N |
| LI..RERIA PEN | TANGANICA WALLNUT | 7323110000K 03410B | JE/ ... L |
| PO..TRO.CINA | REX N. 1121 BROWN | 7353100000M 02020Q | JE/ ... O |

Mod. 94.1153... - Approv. 264177

Layout of ceiling lamps and anemostats

This work is performed cabin by cabin. After automatic subdivision of ceilings into panels, by very simple commands, by pointing the screen cross-hair on the chosen panel, storing is made of the position and type of lamps and of the position and dimensions of holes for anemostats installation. In order to speed up the process, some standard positions of the holes in the various panels are fixed and, if it is necessary, non standard elements can also be very simply stored.

HARDWARE

Man-computer communication within the CASA system is realized through a TEKTRONIX 4014 terminal connected with the Main Computer; the installation of a refresh buffer allows, for the procedures which require this performance, also a limited activity in the refresh mode.
The configuration is completed by a hard-copy connected to the screen and by an off-line plotter for production of all the drawings utilized for design completion, for workshop manufacturing, and for installation on board of all furnishing materials of the superstructures.
The choice of such hardware turned out to be a very profitable compromise from a technical-economical point of view as it unifies the advantages of low purchase and maintenance costs and 'the advantages to offer the capability of moving on the screen geometrical figures even not very complex.

MODULARITY OF THR SYSTEM

The C.A.S.A. system has been designed so that it can be modularly inserted in the company's information system.
With this purpose the System organizes and prepares all data so that they can easily be retrieved from the systems connected with CASA. These systems deal with the handling of all furnishing materials from purchase to arrival of components to the yard, to their assemblying at the workshop, and to their definitive installation on board.

ADVANTAGES

After being exploited on a considerable number of ships the CASA system has widely proved its validity in furnishing design and in workshop documents preparation.

The most significant advantages are:

1 - reduction of technical times for the preparation of the workshop documentation which - (for a prototype ship) - decreased from 12 down to 6 months; this problem is maximally felt when prototype ships with short delivery times are involved;

2 - Reduction of technical office work load which is decreased (in the area interested by the system) from 6000 down to 2000 hours;

3 - Saving on costs of materials in stock, better utilization and reutilization of materials;

4 - Rationalization of -yard's work thanks to a better quality, quantity and quickness of information received.

Further' more utilization of CASA on different types of ships has shown its high flexibility by obtaining excellent results on ferry-boats, tankers, merchant-ship, and off-shore.

# AN INTEGRATION APPROACH TO COMPUTER AIDED DESIGN SYSTEMS FOR SHIP DESIGN

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Mr. Knobel currently manages computer aided design projects for the CAD CAM Division of SofTech. He has worked as a naval architect/structural analyst, designing and analyzing structures of a number of different ship types, and a variety of materials. He was a teaching assistant in naval architecture at MIT for commercial and naval ship design courses. Mr. Knobel has worked as a designer of large custom yachts in aluminum, fiberglass and wood, solving production problems and designing tooling for these vessels. He was also head of the Engineering Applications Computer group of a Washington DC consulting firm.

Mr. Knobel holds a BS degree in naval architecture and marine engineering from Webb Institute, and a MS degree in naval architecture and marine engineering from Massachusetts Institute of Technology.

## ABSTRACT

The use of Computer Aided Design (CAD) tools has become increasingly common in the ship design and manufacturing industries over the last decade. These tools have often evolved from small individual efforts developed by one or two engineers into major programs on which large portions of the ship design effort depend. In many cases the management of the computer system has not kept pace with the evolution of the software.

This paper describes an approach taken to the development of computer systems to minimize some of the resulting problems. The underlying premise is that the objective of the system is to increase the overall productivity of the organization instead of the productivity of any single technical discipline. The conclusions reached were that more consideration should be given to the data storage, management and communication capabilities of current computers by the ship design organizations in addition to the effort of developing design or analysis programs. The conceptual system design that resulted from applying this approach to a particular organization is presented along with a description of the first software item implementing this concept.

## ACKNOWLEDGEMENT

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The author wishes to express his thanks for the assistance of Mr. Craig Carlson, Mr. Phil Anklowitz and Mr. Jim Lisnyk of the Naval Sea Systems Command (NAVSEA).

The conclusions and opinions presented are those of the author and are not associated with the views of the Naval Sea Systems Command.

## Section 1

## INTRODUCTION

The use of Computer-Aided Design (CAD) technology has become a major part of the ship design and manufacturing projects. The programs being used have evolved from small simple routines to complex groups of programs that work together. The present trend is towards an increasing reliance on computer aids to the ship design process. These systems are expensive to implement and the resources for their development are usually limited. We are now faced with the task of planning and managing the further development of these aids to maximize the return on investment.

The technology to perform the separate pieces of a Itpaperless design", exists now, that is, designing a ship where the primary means of recording and manipulating the design is the computer system. There is potential for great improvement in ship design productivity, and hence profitability, with a paperless design" system. However, no system with all the separate pieces integrated into a unified system has yet been developed. Some factors responsible for this situation are the cost of such a system, and possibly the need for a different approach to their development. In particular, the management of ship design organizations must realize that the CAD systems are essential in the ship design efforts and that major productivity gains are possible through focusing management attention and resources on those systems.

This paper will discuss an approach used to help determine where computer technology development efforts may be focused to provide the greatest improvements in the productivity of the overall organization.

We will then briefly describe a study of a system where this approach was followed. A conceptual integrated system design reflecting the conclusions of that study will be described. The software efforts to develop the data management, data storage and communications capabilities of the computer system for CAD will be presented.

Section 2

# APPROACH TO COMPUTER AIDED DESIGN SYSTEMS

This section presents the general approach SofTech has found useful in system design and analysis problems in both the Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) environments. The specific software developed may have limited applications. However, the approach may be found useful in tackling a wide variety of system productivity and profitability problems. Later sections will describe the results of applying this approach to a specific task.

## 2.1 Define the Organizational Objectives

The first step in the design of any system is to develop an understanding of the objectives of the organization that will utilize the system. This is a seemingly obvious step but surprisingly it is rarely accomplished.

Systems for Computer Aided Manufacturing may have relatively straight-forward objectives; for example, to double the production capacity of a factory. Computer Aided Design systems have not always lent themselves to consideration in the same fashion. It is not easy to define the productivity of a design organization, as the product is often not readily quantifiable. As a result, many times programs are developed without regard as to whether they will actually improve the productivity and profitability of the overall organization. So while it is technically feasible to perform a great many functions with current computers, the first step is to determine’ the criteria of the overall organization for the success of a computer system. The overall organization’s point of view in many cases is very different from that of the design engineers.

An analogy that may be useful is the visualization of the design organization, a collection of people, hardware and software, as a "black box" system. Resources are the inputs and designs are the outputs. The organizational objectives may be to increase these outputs while maintaining a constant level of resource inputs. (Figure 2-l).

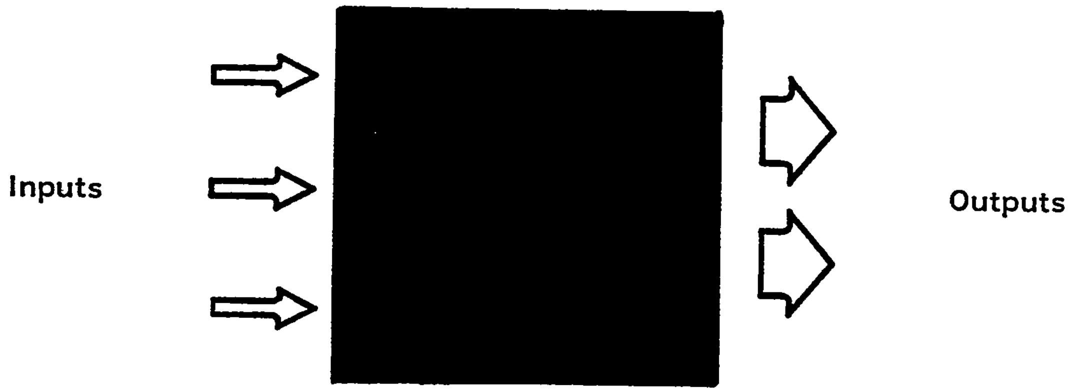


Figure 2-1. Black Box

The process of determining these objectives can be time consuming. SofTech usually conducts a series of interviews and reviews independently with the organization management. The number of implied, undocumented objectives or goals "discovered" during this process is often surprising and very useful to the managers.

## 2.2 Understand the System

Once the overall objectives are defined we can progress to analyzing the system. Through studying the system we can determine how components collectively produce the design as an output. We may also begin to identify problem areas.

There are often many people who will say that they understand exactly how their design process works. It is important to realize that each member of a design organization may have a different view of how the design is accomplished, and all may be equally correct. Each personnel role in the design system, engineer, manager, and administrator, has the

potential for a different viewpoint of the system. The design process may consist of balancing tradeoffs to a design manager, while it is a process of calculations to a designer. We have found that oftentimes the viewpoint of the organizational manager is not known to those actually developing the CAD systems.

The process of learning a system is akin to developing a schematic of the inside of our previously mentioned "black box." (Figure 2-2).

That is, we develop an understanding of what paths and transformations internal to the system are necessary to develop the output of the system. We also learn what areas have a minimal impact on the factors we are interested in. In fact we may have to develop a different "schematic" for each viewpoint to really understand how the system functions.

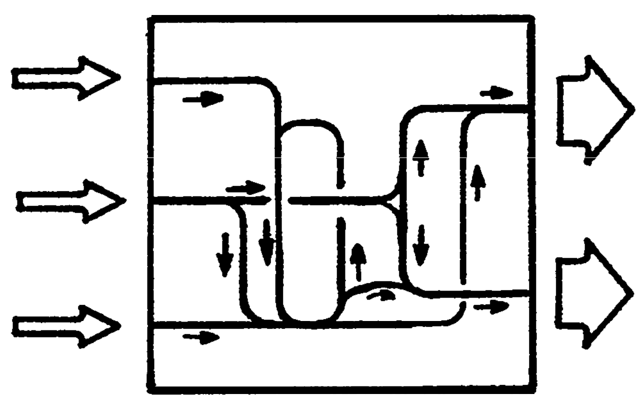

Figure 2-2. Understand the System

2.3 Identify Needs

When it is reasonably certain that the organizational objectives and the nature of the design or manufacturing process are understood, the "needs" of the system can be identified.

By the term "need" we mean a deficiency, bottleneck or problem in the process. If we think of the design process as a black box with a maze of interconnecting pipes linking the input to the output, the "need" would be the areas of restriction of the flow. These may be ‘blockages or malfunctions or other items that may be functioning properly but are of insufficient capacity. (Figure 2-3).

In many cases the “needs" of a system will be identified during the process of learning how the system works. It is important that we evaluate these "needs" on the basis of what we hope to accomplish. In our case it is to increase the overall design efficiency.

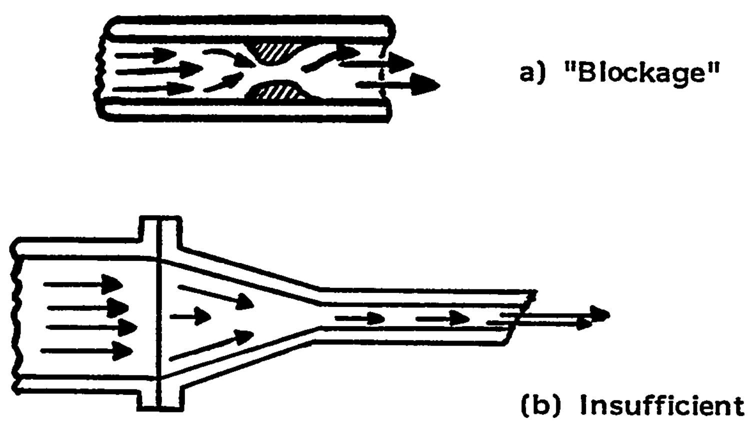


Figure 2-3. “Needs

## 2.4 Scoping the System

In most cases, there are more problems than resources available to solve them. Therefore, the "needs" must be prioritized based on the overall system objectives. In the analogy of the "black box" system only a number of the identified blockages can be improved. It is our job to determine which efforts will provide the greatest return on investment.

Management must take an active interest in this step of the process. There are limits to what can be accomplished with a fixed level of resources. Often, focusing the resources on one area may do more to improve productivity than attempting to apply an uniform effort to all the problems. At this time the management can often be made aware of how much their system can be improved with a functioning CAD operation.

## 2.5 Formulate Solutions

Once areas of the system in need are identified, an attempt can be made to formulate a solution to each one. This is much easier to talk about than to actually accomplish. Going back to our "black box" system analogy we have several choices.

If there is a “blockage," or malfunction of an item, we can possibly correct it.

If there is an area of insufficient capacity, we can enlarge the capacity of the existing unit.

The third possibility is to change the system configuration, i.e., reroute the flow or change the boundaries of the "box."

It is impossible to supply a formula for developing specific solutions. Many times the operational staff of the project can contribute a great deal to the development of solutions if a suitable forum is provided. Our (SofTech) tasks have often been to communicate the "fixes" envisioned by engineers to management.

## 2.6 Implement Solutions

Once the solutions are developed they may be subject to further changes due to cost, time constraints or a redefinition of the overall objectives. When these are finalized there remains the problems of implementation. The solution may be writing software, acquiring hardware, or reorganizing personnel in the design process. Each of these projects would now have their own approach to accomplishing a more defined set of detailed objectives.

## 2.7 Evaluation

Once the changes are made to the system they should be evaluated with respect to the defined organizational objectives.

"Did the items implemented accomplish the desired objective? And if not, why?"

The answer may be outside conditions impacting the system or a failure to fully understand the system and its problems. Establishing a record of the successes and failures and applying that knowledge to succeeding efforts is a valuable part of the process. This body of knowledge provides much of the background for determining the potential returns on items not easy to quantify.

## Section 3

## APPLICATION OF APPROACH TO NAVSEA 55

This section will describe the results of applying the presented approach to a task of improving design productivity of a specific ship design organization. The organization studied was the Naval Sea Systems Command (NAVSEA), Code 55, the Hull Design Group.

### 3.1 Organizational Objectives

In the particular project being discussed, the organizational objectives were stated as:

> "to achieve an increase in design productivity of better than five to one."

The reasons for establishing this objective are a predicted large increase in the ship design workload and the shortage of experienced, trained naval architects. Not only are there governmental personnel ceilings, but it is estimated that even if these limits were relaxed there are simply not enough trained engineers available nationwide.

Some secondary objectives were in fact constraints to the solutions. They are: the proposed improvements must be available soon; they must not disrupt the present ship design process; and of course, the cost must be minimal.

### 3.2 The NAVSEA Design Process

The engineering system studied was the Hull Design Group of the Naval Sea System's Command, Code 55.

This organization is responsible for defining the geometry, or envelope, of a ship. This includes the ship structure, internal and topside arrangements, stability, speed vs. power, etc. This group works closely with similar organizations having responsibility for weapons, electronics, and machinery. As can be seen from the following paragraphs it is fairly typical of a ship design organization.

### 3.2.1 Design Organization

The Hull Group, NAVSEA 55, organization is subdivided into smaller groups by a functional breakdown. Each organizational group is responsible for specific sections of the ship design. As an example, one group would be responsible for developing the ship's hull geometry. As a design progresses a task required in the geometry development will be assigned to an engineer. This engineer will generally continue to be responsible for this task throughout the many iterations of the ship design.

Periodically, the ship design will be ltissued.ll This means that the current state of the entire design at that point in time will be collected and approved as a ttbaseline.tt At these steps the engineers' supervisor will be responsible for the approval or "sign-off" of a drawing or a set of information. The aggregate of these approved drawings or information sets comprises the "design."

The engineer will start on the next iteration of his task using this "baseline" package. During iterations of the "baseline" the engineer will communicate, either formally or informally, with other designers to obtain more up-to-date information or information not collected into the formal "issue."

### 3.2.2 Current CAD Software

The "typical" engineer may perform one or two specific design tasks. If supported by the CAD system, these tasks will usually be performed by single batch-type programs, or stand-alone interactive programs. Programs of these types usually have defined format inputs, and defined format outputs. Where necessary, data translation is accomplished by "interface" routines. The design process is, therefore, a collection of individual programs and logically separate data items in the form of "files."

### 3.2.3 Hardware

The NAVSEA computer hardware environment includes a number of separate mainframe's and mini-computers. Included are IBM, CDC and DEC equipment "linked" via file transfer capabilities in a batch mode.

The user has remote access to these systems over dial-up phone lines, usually at 1200 baud. Terminals include TEKTRONIX 4014's, "Dumb" CRT's, and TTY type units.

## 3.3 Needs

The discussion of the "needs" of a design organization requires us to step back and examine the process from some distance.

A typical design organization may be as shown in Figure 3-l. The organization is a ordered assemblage of people, information and tools. The people may be design managers, administrators or engineers. The information consists of procedures, or how things are accomplished and data about the particular technical subject. The tools may be technical items such as computer and programs or more basic items like drafting supplies and services.

Obviously, a problem with any one of these areas can have a negative impact on productivity. We will only focus on those areas potentially suited for computer support, and in particular those related to the technical design information.

The elements of the design process that are most involved with the design information are shown in Figure 3-2. We have identified the engineer (circle), the manager (square), and information (triangles). Arrows show typical flows of information. The information needed for a design task includes procedures, historical data, the project data, and various stages of approved design data.

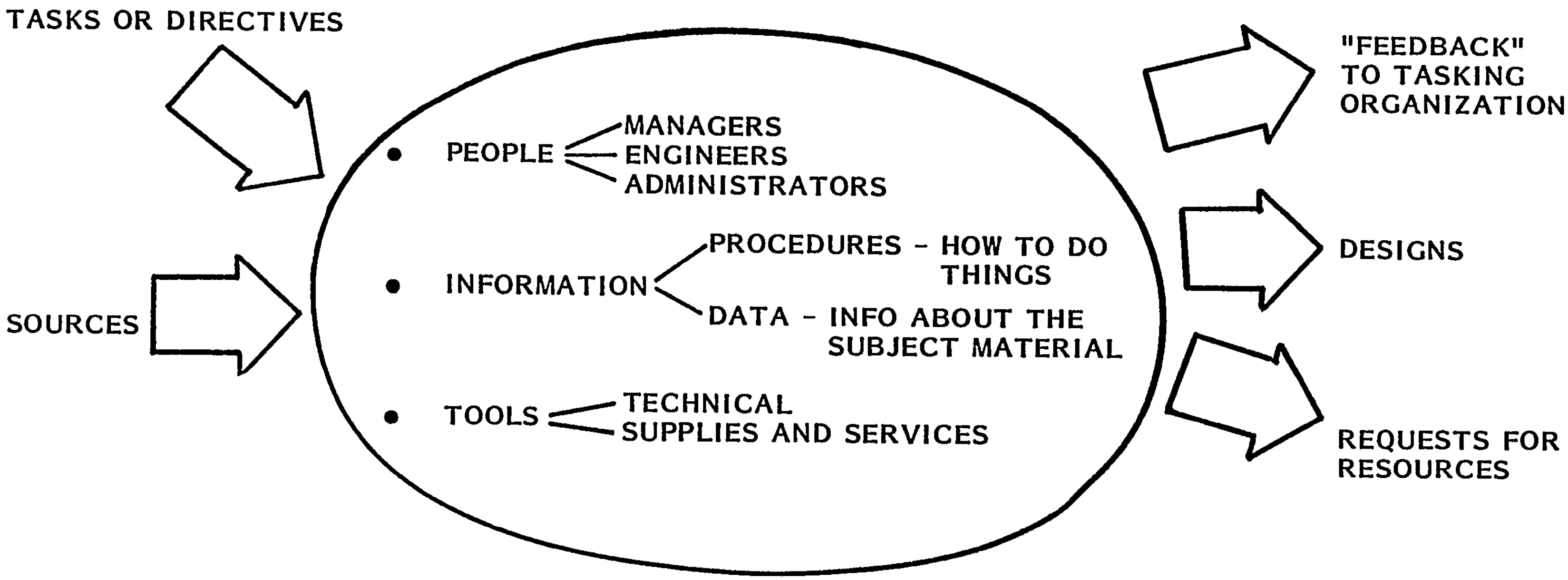


Figure 3-1. Design Organization

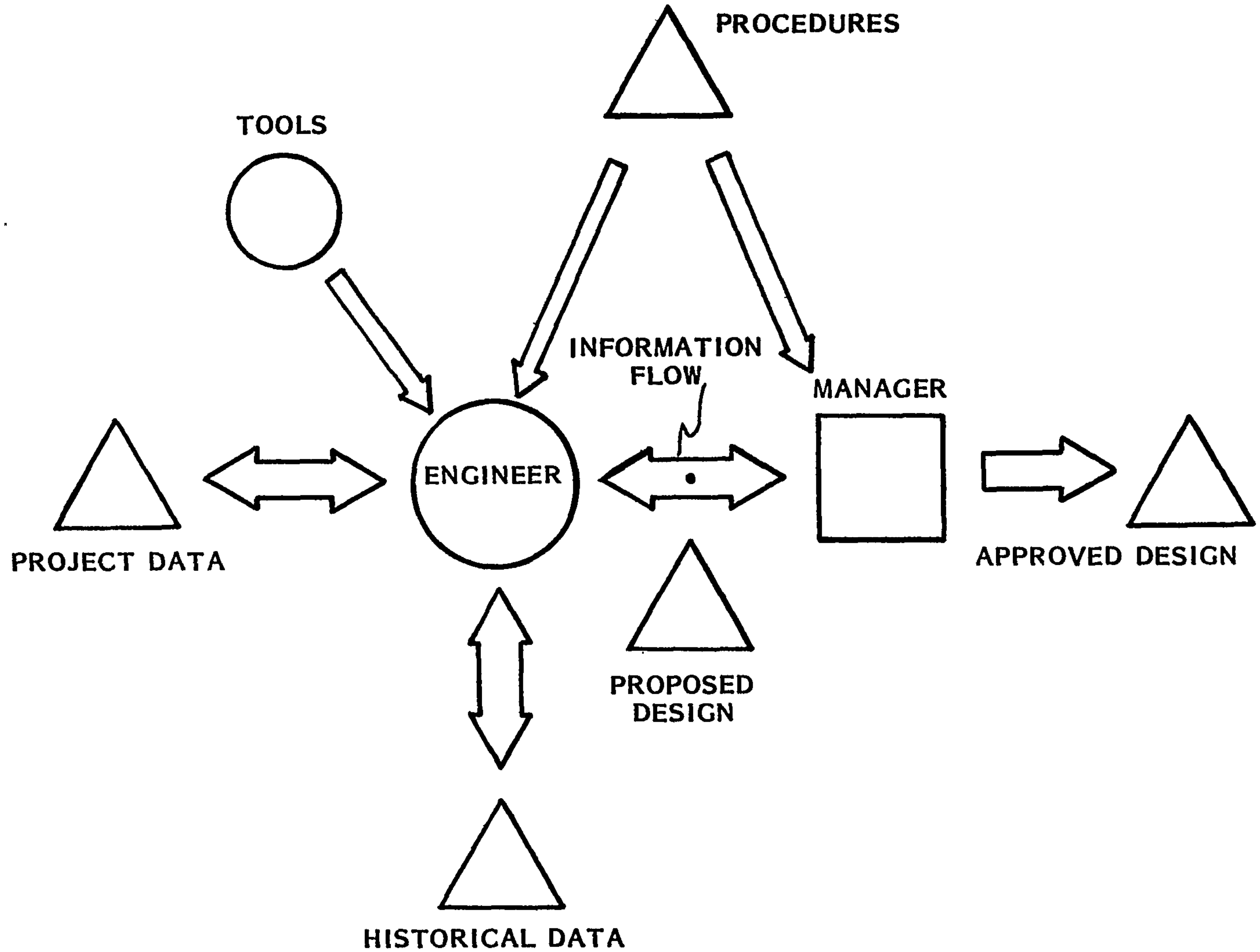


Figure 3-2. Elements of the Design Process

When considering a section of organization, we come up with the picture shown in Figure 3-3. More than one engineer is using information and there are a large number of data flows. Some of these information transfers are of the program-to-program type, but many more are informal or paper transmittals.

The evaluation of needs for this project was performed at the level shown in Figure 3-3. The question posed was: "What can be done to make this system of information derivation, transfer and approval work more efficiently?". The evaluation was accomplished by examining each of the elements of the design process other than the personnel.

### 3.3.1 Information "needs"

The information "needs" include the storage and retrieval of procedures, historical data, and data on the current ship design project, and the flow of these items between engineers.

The design community as a whole does not have common procedures for the automated storage and retrieval of technical information. The entire area of developing a usable, responsive system of data handling, communication, and storage for a large organization needs to be addressed. Items of particular attention are: storing and protecting approved drawings and design items; providing communication among engineers, between engineers and managers; and standardization of data storage between departments.

### 3.3.2 Tools "needs"

The subject of tools includes task-specific items such as computer programs and system-wide tools such as computers.

One of the major "needs" identified was the scattering of operations among many different computers. This has resulted in different sets of software for each machine and different procedures for its use from one machine to another.

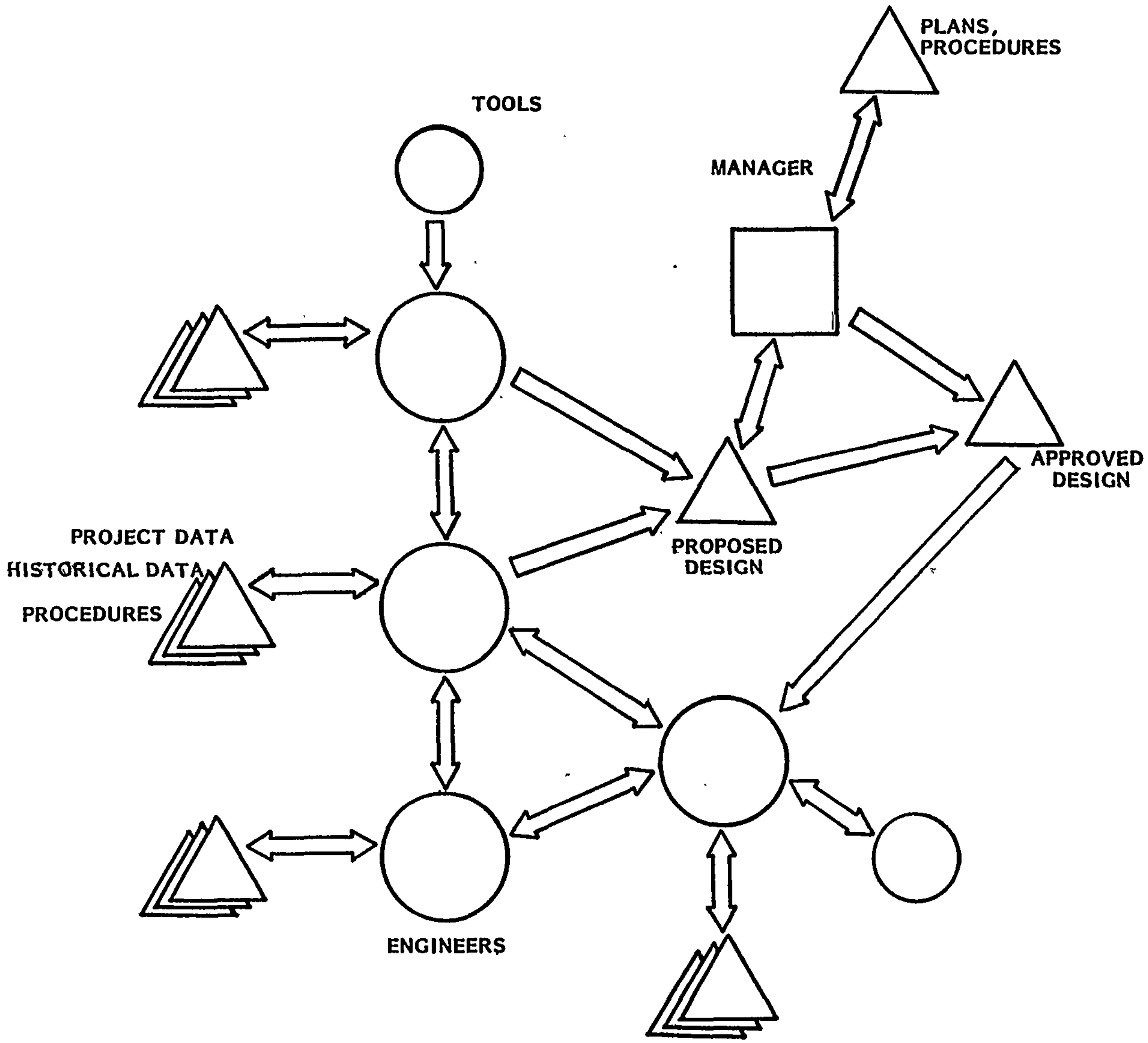


Figure 3-3. The Design Process

"Needs" in the area of specific tasks were found to be: to increase the utility of existing programs by making them more "user-friendly," and the continued development of specific programs. Another problem area was the support or maintenance of the software already developed. In short, many independent applications programs are available but other factors render them less useful than they might otherwise be.

The "needs" identified here are typical of many current design organizations. Present systems are the products of evolution and the work of many engineers working independently. The result is many independent programs working correctly, exactly as they were supposed to. The "need" or problem has only occurred because advances in technology have made much more capability feasible.

## 3.4 Scope

The problems identified were of the following categories:

- Insufficient or inadequate application programs,
- Overall system hardware,
- Communications among engineers,
- Ease of use of the computer system,
- Data storage, and
- Lack of common system design.

In evaluating the "needs" versus the objective of a five-to-one increase in productivity it is clear that adding one or more independent programs cannot possibly provide the necessary increase. The only course left is to tackle the system-wide areas and make use of current advances in communications, data storage and management.

It was decided that while application programs were being developed, a concurrent project would work towards a common hardware, software, and management environment.

### 3.5 Solutions

The major proposed solutions, or items thought to provide an overall increase in system productivity, were:

a Move all operations onto one hardware facility. This would eliminate much of the communications difficulties and differences in operations, and provide for easier maintenance and support.

l Provide a dedicated system support group for system control, software development and maintenance, and hardware operation. This would alleviate much of the burden on some design engineers and provide more reliable, consistent service throughout.

Develop an overall integration concept for data and programs utilizing current communications, data management and control capabilities. This would be the start of evolution towards an integrated system providing ease of use to the engineers.

### 3.6 Selection of Implementation Items

The study determined several possible improvements to the design process. As with any system, cost and other constraints determine which items are implemented.

In this case, while most engineers agree on the benefits of moving operations to one computer system, it may not be an easy thing to accomplish. Similarly, changes in the design process such as adding a software support function are also difficult to effect.

SofTech was tasked to begin work on the third proposal, to plan for an integrated system of people, software and hardware. This solution was further constrained by the requirement for rapid implementation and minimal disruption of ongoing work. This has resulted in a conceptual system design and a prototype program to improve data management and program utility. The software item is referred to as the “File Manager.”

# Section 4

# PROPOSED SYSTEM DESIGN

In this section the system design concept will be described. This design is an attempt to develop an integrated system of people, software and hardware. It is based upon a low-cost, low-disruption evolution from the present computer aided design environment.

## 4.1 Design Considerations

Before we can specify a solution to the problems some discussion of the available and forthcoming advances in CAD technology is appropriate. The field is developing so rapidly that it is difficult to implement a system before advances render it obsolete. This section will discuss some of the considerations and technological advances that must be taken into .account when planning a Computer-Aided Design system.

### 4.1.1 Drawing Based System

In the traditional design process, based upon individual drawings, there is limited indexing and cross referencing of information. A particular drawing may be catalogued by title, drawing number and revision date. Information describing separate pieces of the ship that are shown on the drawing might be detailed in another drawing. In general, though there is no cross-referencing between drawings for a more detailed description of parts of the design (Figure 4-l).

Off-the-shelf drafting computer systems that can automate the drawing process are available. These systems do not necessarily change any of the operations; they are essentially an electronic drafting board and drawing file.

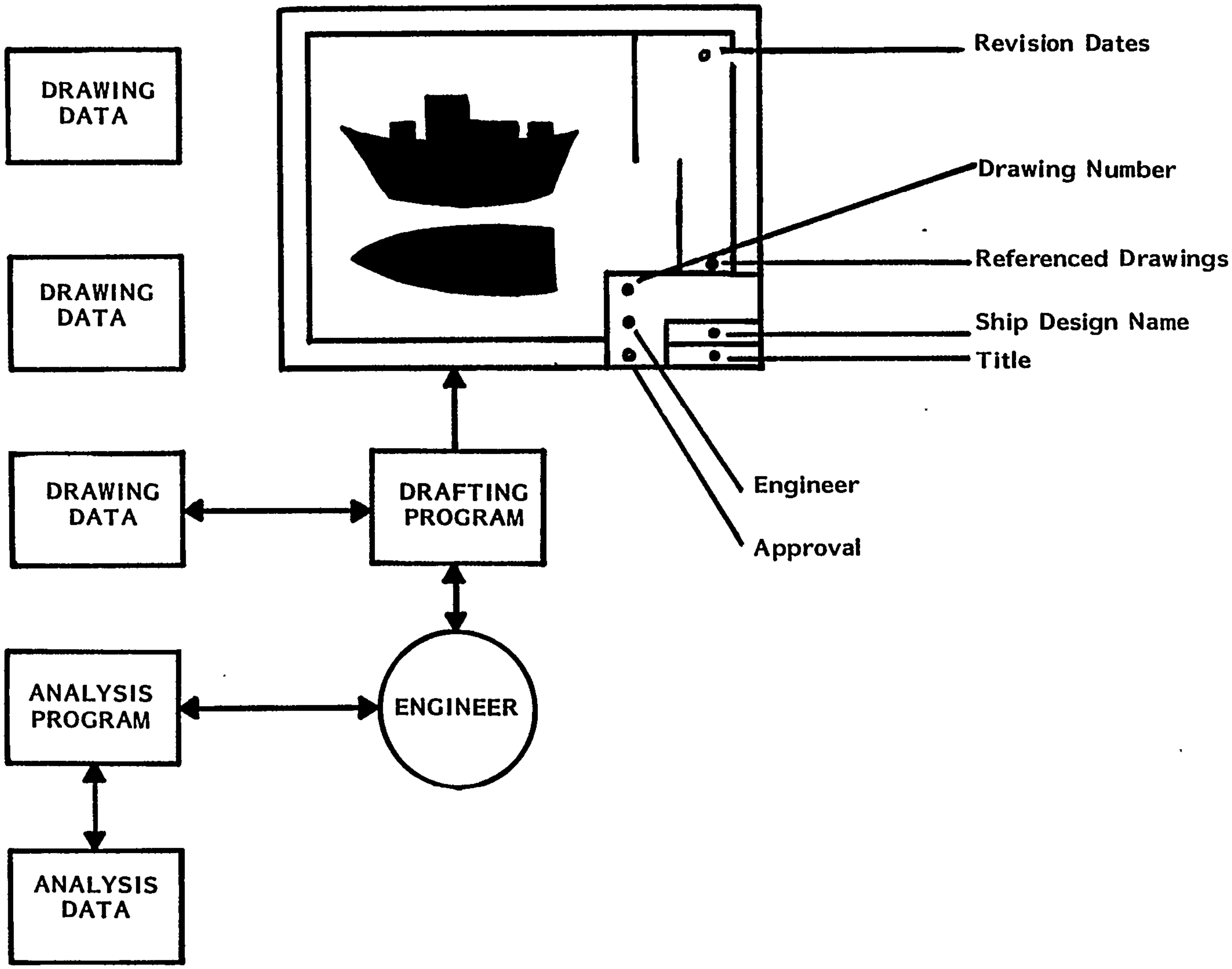


Figure 4-1. Drawing Based System

#### 4.1.2 The Computer System as the Design Media

For the last hundred years ship designs have been performed using the drawing as the means of recording design information and communication between engineers and managers. There now exists an alternate medium to serve these functions, the computer system. While illustrations will not be replaced for the communication of concepts to individuals, it is likely that the primary means of recording information will become the computer system, since it offers instant access, change, distribution and control of information not available to a “hard” media. This transition is already underway, and when it occurs without management awareness it may be the source of problems during ship design projects.

If we accept the premise that the design will eventually be performed using the computer system as the media, we must try to determine what are the implications of this change and how they might be managed.

The properties of the computer system that provide its benefits are the same ones that may cause new areas of concern. These are: ease and speed of changing information, the ability to correlate or “track” information from many different viewpoints, the ability to use the computer as a communications center, the ability to store large quantities of information, and the ability to perform computations directly on the design data. All of these different "viewpoints" and capabilities require management. For example, the organization must control who can, or cannot, change information.

Additionally, we must always remember that the system will only do exactly what we tell it to do. Formulating the correct directions to the system is the problem.

#### 4.1.3 Correlation of Information

The computer system provides a great deal of information storage capability. Possibly more useful than the quantities of data stored, are its ability, when working with database software, to provide many different means of indexing or accessing information. Each information item in the computer may have associated with it one or more parameters to facilitate the recalling of that stored information. When the same information is used by different people, a separate parameter may be assigned each person. We term the parameters that a person uses to organize his storage and recovery of information his Viewpoint." Potentially, there are as many different viewpoints as there are users of the information. Therefore, in the computer system we cannot simply keep track of a number of drawings, we must manage the requirement to access the information in many different fashions.

#### 4.1.4 Directing the Computer System

The computer is a very powerful tool for engineering purposes with one major challenge. The user must direct the computer to perform his functions by specifying a series of very small computational steps. One cannot store information in the computer without specifying exactly how it will be stored and the ways it may be recalled. Database packages will help with the mechanics of this process but will not help with the specification of what is to be stored or how it will be recalled. The development of this specification requires that we decide in what units the information will be stored, or how big the groups are, by what methods may the data be recalled, and how the information is related to other stored data. This must be specified for every identifiable type of item that will be stored in the computer. Developing this description of the design information can require a great deal of effort. This description is sometimes referred to in database terminology as a "schema."

### 4.1.5 Computer Database Design System

Computer systems have the potential for vastly increasing the level of detail of the breakdown and storage of information. These systems differ from the "electronic drawing board" in that information about items of the ship design are stored separately. When information or an illustration is required, the desired data is selected from these separate items and presented in the desired format (Figure 4-2).

This approach has the potential for a great deal more flexibility and automation of the design effort. For instance, once the locations of hull equipments and weights are entered, this system could perform the moment calculations directly from the stored data.

### 4.1.6 Subdivision of the Design Data

One of the major problems in developing a CAD system is determining how to organize and subdivide the stored data. With a finer "mesh," i .e, greater detail, there is more potential for automation of functions and non-redundant storage of information, commonly termed integration. On the other hand, a coarse "mesh" provides fewer separate groups of information to manage.

Current database software enables the usage of the finer mesh from a software viewpoint. However, these databases do not solve the problems of managing the ship design information at this greater level of detail.

The main impediment to developing an integrated system is the limited techniques for managing the greater numbers of items that would now comprise the design.

### 4.1.7 The Electronic Design Office

If we accept the premise that the computer system will become the design media, we arrive at the concept of the "electronic design office". That is, we must implement many of the functions that we take for granted in a paper-oriented office as part of the computer system.

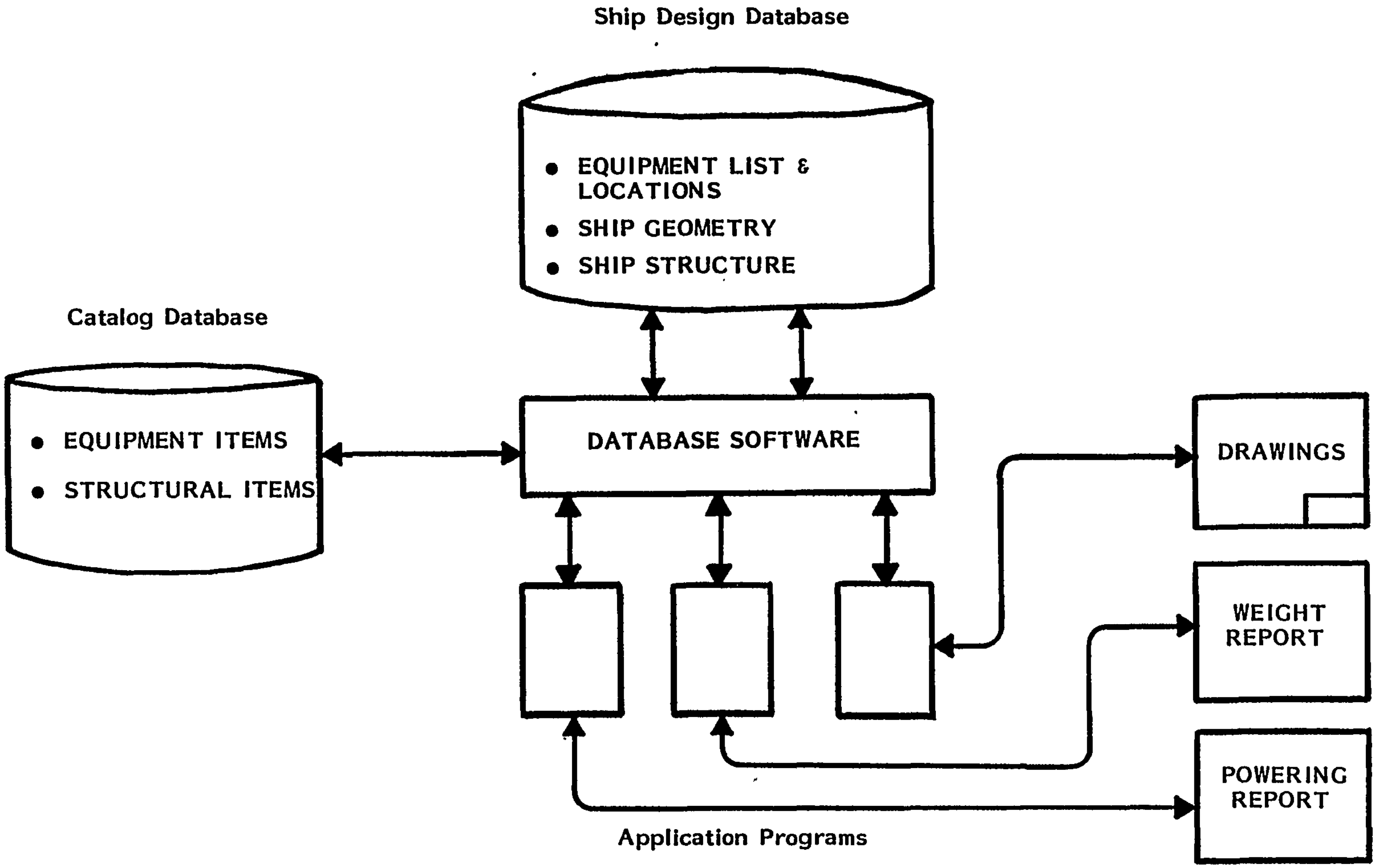


Figure 4-2. Database System

For example, as design projects and staffs have grown larger and more complex, the methods of management have not changed. In the past, design decisions could be considered, action taken, and information distributed by a small group of personnel looking over a set of drawings.

In the future this function must be performed by operating on machine-stored data, and instructing the system to perform the necessary distribution.

The current data storage systems can implement the drawing file and very importantly, track all of the drawing changes and revisions. The engineering system can be implemented so that each designer has not only his own hardware workstation, or drafting table, but his own storage areas free from outside intrusion as well.

The computers communications capability can perform the rapid distribution of new "prints" of a drawing to widely scattered designers. It may also provide the ability to hold a drafting board review over different terminals. A drawing with informal notes can be transmitted to another engineer with the same ease that formerly was used to bring it across the room.

There are a large number of functions performed in a design office that are not design or analysis. In fact, too little of the designer's time is spent in engineering. Much of their time is spent chasing down information, sitting in meetings, setting up input data and fighting unruly computers. Technology available only in the last few years can help expedite much of these efforts; except, probably, the meetings.

The proposed approach must answer "How will this be implemented?"

## 4.2 System Design

The system design presented here stems from the specified requirements and the aforementioned considerations. The requirements are that it provide an increase in productivity; be available soon; be low cost; be compatible with existing operations software and data, and be easy to use. The other considerations determine in which direction we

would like to evolve. The system should be compatible with the present drawing-based method of design, but provide a transition towards a database concept. It should accommodate a fine data "mesh" as well. It should be able to accommodate multiple viewpoints of different personnel. It should evolve towards the "electronic design office" where the computer serves as the media for the design.

The “integration approach” is an attempt to solve this family of problems.

The drawing-based system shown in Figure 4-l provides compatibility with some of the existing software and methods. It essentially automates the drafting tasks, and may have a separate system for analysis. However, this system does not provide for evolution to a direct integration of analysis-to-design as the drawings are the only record of the design.

The database system of Figure 4-2 provides more evolutionary capability. It allows drawings to be generated from a central record of the ship design. In fact it accomplishes all of the desired functions, but only theoretically. The performance and management problems with systems of this type have limited their successful use to very small operations.

The proposed system is shown in Figure 4-3. Essentially this uses the same element as the database system. We will store information about the ship, not records of lines that describe the ship's components. The difference is that the database, and the control of the data is distributed to match the project structure.

The data is broken into the fine "mesh" suitable for highly integrated programs and data access, but it is grouped in sets small enough to be manageable. This approach is feasible because in the design process there is very little requirement for great detail other than to the staff directly responsible for a segment of the design. The distribution of the database in this fashion also removes many of the

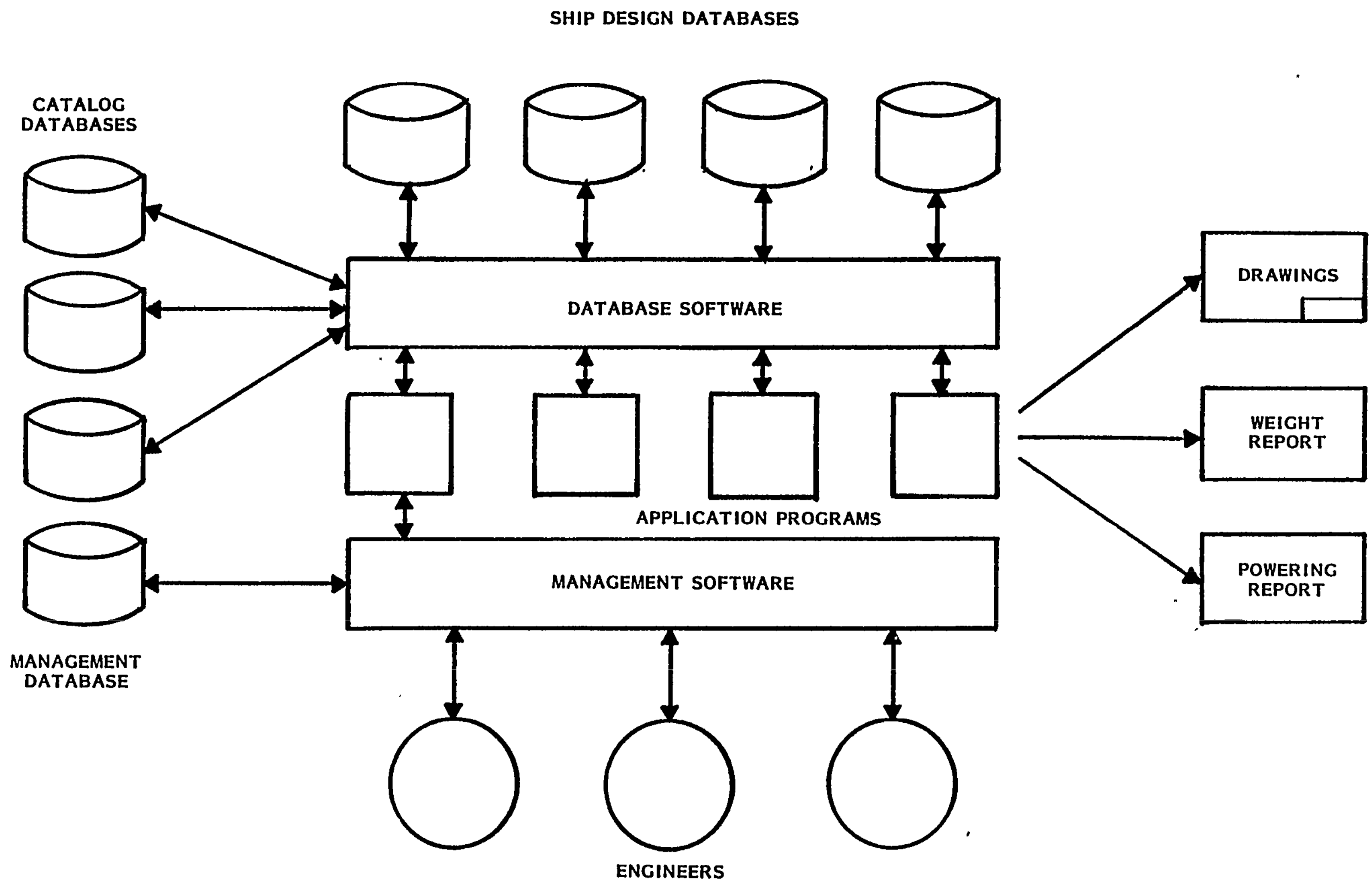


Figure 4-3. Proposed System Design

physical performance limitations. In addition, the system includes a management system to keep track of this distribution, and to provide for the essential transfer of information between groups.

#### 4.2.1 Data Structure

The tradeoff presented is that of a fine "mesh" or subdivision of data items for program integration and flexibility versus a coarser "mesh" that is familiar to engineers and is easier to manage.

The selected integration approach is to have a different level of subdivision for management purposes from that used for the software data access. The management subdivision will be much the same as the present drawing level of detail. The software storage of data will start off with the current file access methods and evolve toward a database system.

The key to understanding the approach is that the physical implementation of the information on the computer does not have to match the user's perspective of that information. Although an engineer may wish to see all the ship's geometry information at one time, that does not require that all the information be stored in the same place, or even in the same manner. What is required is that the engineer have an access-method to the data that will yield the desired result. Allowing different access methods or viewpoints to the same information gives us the flexibility to have both the fine and the coarse mesh we need for the design process.

The approach of distribution of data and its control, while maintaining a separate management system, provides the capability to transition smoothly from current software to the "electronic office." The management system may be implemented by treating each type of present data file as a separate database or database segment. The existing data access methods can be utilized until the requirement for a finer "mesh" or other needs dictate a change. Thus, existing data access methods can be used side-by-side with newer database techniques, with the management system handling the switching between them.

Perhaps an analogy to a large engineering library will convey the concept more clearly. If the library has only one librarian, and the books are cataloged by a system known only to that librarian we have the case of a central database. If the librarian is very, very fast users may get what they need. If the librarian is not fast, there will be undesirable delays.

The present system is that of having many separate libraries. Each has books on one or more subjects, and overlaps exist. Moreover there are no librarians, only users of the different libraries who may or may not be available to help others.

The proposed system includes the establishment of separate libraries and cataloging them, but keeping **individual indexes** for each one. A central librarian directs the user to a librarian in charge of the particular section he requires. From then on the user will work directly with that local librarian. In our case we follow the same sequence for storing information as well.

4.2.2 Program Structure

The conceptual design is a system of computer programs, engineers, databases and management.

The computer programs of the system design would be similar to those currently in use. The trend has been for programs to increase in size and complexity. This has come about mostly because of the difficulty of data access and management. The engineer pulled in an entire "management unit" of information and performed his operations on it.

The conceptual system design calls for the development of smaller programs performing one or two functions. These programs are easier to implement with database technology and may be "strung" together to achieve the same results as the larger programs, if required.

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#### 4.2.3 Engineers Viewpoint

The proposed system will allow the engineer to function in the same manner as they do now, with the substitution of the computer terminal for the drafting board.

The engineer will be responsible for individual tasks. These will be accomplished by design, analysis or drafting programs. The engineer will have complete control over his information, and will be able to permit or restrict access as he desires.

#### 4.2.4 Design Managers

The project managers will be responsible for approving design information stored on the computer and for directing analyses or changes to the design. Therefore, the system must be able to record and "freeze" information on approval. There must be the computer equivalent of setting a "baseline" of a design.

Change directives must also be coupled with the design data. If a change based upon a drawing or report is directed, that particular collection of data must not vanish when the engineer performs his next update. The recordkeeping that goes along with the drawing system must be implemented on the computer.

#### 4.2.5 Data Administration

With the development of software to manage data storage, a data administration function must be initiated. The subdivision of data, its place in the databases, and its retrieval methods cannot be readily distributed.

This function is analogous to the setting up of the central librarian, who in turn will hire and manage the supporting specific librarians.

### 4.2.6 Program Development and Maintenance

Developing programs under this sytem should be simpler because of the separation of data access methods from the programs. By referring to the data administration documentation, programs may call previously set up data access methods.

As the data access methods are central to the entire system, control will have to be exercised over their operation. Independent software developments must be checked for authority, security and project control before allowing data to be changed.

## 4.3 File Manager

The "File Manager" is a program being developed to aid in the use of the computer aided design program and to help manage the design data. Its objective is to remove the need to know any specific computer language or operations from the engineer . It is designed to be the first step toward the management part of an integrated system of programs and data. The first "BUILO" of the program is now in operational evaluation and test. updates and extensions are planned to result in "BUILD TWO" by the Spring of 1983.

The present environment utilizes data files stored by different naming conventions on each computer. For example, some conventions limit the user to a seven-letter filename. The overhead involved as the engineers learn the computer file manipulation commands and track their files has become a noticeable problem.

### 4.3.1 File Manager Data Structure

The File Manager (FM) provides a structure to aid the engineer in the storage and recall of ship design information. The database is divided into ship design projects, ship design variants inside a project, and files that are parts of a particular design. Files that are part of a design are further categorized by their approval status. They may be

approved files, i.e, files that constitute a design baseline. Other classifications include "past approved files" and proposed files representing previous baselines and the target for the next baseline, respectively.

There will also exist “private files” directly under the control of the design engineers as part of the design. One engineer may work on many projects or designs, but a particular file of information will only be associated with one design (Figure 4-4). The File Manager will manage information about existing files at a management level. As new software is developed the file manager will be extended to include the separation of programs from data access routines.

### 4.3.2 File Manager Data Handling

The file manager will provide each engineer with the ability to add, delete, rename and search for files by using simple commands selected from a menu. For example, the engineer may request a list of all files owned by an engineer, or all files of a certain type, or all files written on a specific date.

More importantly, the system will deal in terms that have significance to the engineer. The system will remove all "computerese" from the interaction with the user. It will at the same time permit sophisticated operations to be performed.

### 4.3.3 File Manager Program Interface

The file manager will provide a means for the engineer to initiate a programs operation by choosing simple commands from a menu presented to him. The system will ensure that only the correct type of files are used as input to each program, and that they are of the same design as is currently being performed.

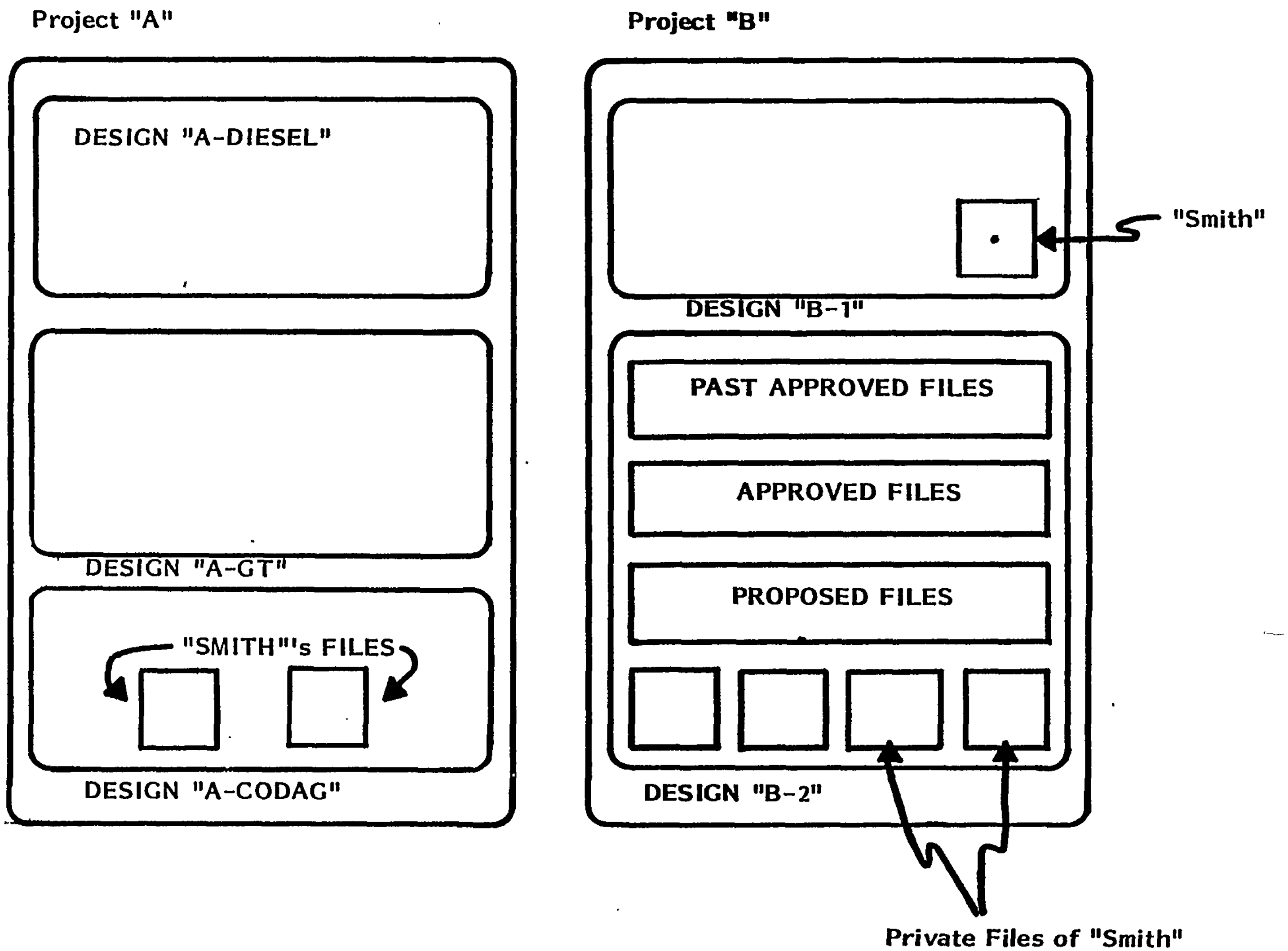


Figure 4-4. File Manager Data Structure

## Section 5

## SUMMARY

The conclusions of our study are that in some ship design environments the best return on an investment in computer aided design technology may be in integrating existing software. This is to some extent dependent upon the size of the design organization, as smaller groups do not have the same management problems.

The integration approach, or conceptual design offers a transition from current methods towards a database system or "electronic design office" (Figure 5-l). The approach will smooth the transition, allow easier acclimation of users, and more gradual cost of implementation. It will lessen the work involved by allowing us to learn as we go along instead of plunging headlong into a major CAD system re-write.

We believe that a similar approach toward increasing productivity or profitability may be applicable to a number of other design or manufacturing environments, where compatibility with existing operations, evolution towards advanced systems and gradual implementation are important considerations.

- Organizations must focus on the best return on their CAD investment.
- The trend is towards the **Electronic Design Office", the computer is the design media.
- It is possible to plan a smooth transition from current systems to the "Electronic Design Office"

Figure 5-l. Summary

## SMALL SHIPYARD PRODUCTIVITY INCREASES THROUGH INTEGRATED MANPOWER, SCHEDULE AND MATERIAL CONTROL

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Mr. Deschamps has extensive experience in applying mathematics and computer methods to solve such practical problems as the minimizing of company costs and production schedules. He developed specialized statistical techniques that accurately predict future costs and schedule changes based upon current performance feedback information, and developed computer software specially tailored to meet the needs of large-scale project planning and cost/schedule control. He assisted the Canadian Government to develop specifications for cost/schedule control systems and management reporting requirements for Government contractors, and provided extensive consulting and planning/scheduling services to companies in the United States and Canada to improve production costs and schedules using improved methods for planning and company management information.

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## 1.0 SUMMARY

The authors describe the need for fully integrating all aspects of shipbuilding so that current resources can be utilized in the most effective and cost-efficient way possible. The integration of manpower, scheduling, and material control using mini-computer planning, and cost/schedule control systems have proved to be extremely beneficial to small and medium sized shipyards. These systems have given management an added insight into areas that have been troublesome. Now, corrective action can be applied and the results measured quickly, directly, and accurately.

By integrating all efforts of the shipyard plan, relative merits of new production techniques can be measured and evaluated. This extension of management visibility and control permits the shipyard to implement new technologies with far more confidence than possible before.

## 2.0 INTRODUCTION

The over-riding concern in shipbuilding today is how to increase productivity in the best way possible.

Much of the current difficulty North American shipyards face is an inability to compete on the world market because, quite simply, our ships cost too much. Costs for labor and material have escalated to the point where the free market system can no longer guarantee that our shipyards will compete successfully with shipyards abroad.

And while we face very high unit costs for labor and material, the fact remains that our productivity (the measure of our success in utilizing these resources) has declined greatly. Foreign shipyards, on the other hand, have implemented new processes and procedures that utilize the resources needed for ship construction far more efficiently, regardless of the higher unit costs involved.

Considerable attention has been focused upon the benefits of computer-aided design (CAD) and computer-aided manufacturing (CAM). Surely these applications have great potential. But while the promised benefits of these new systems is most encouraging, too often too little thought. is directed to what can be done to make existing facilities and resources more efficient and productive.

What needs to be asked is this: why do foreign yards build ships with HALF or less production manhours than do North American yards? The answer can be found not so much in their more advanced facilities and "high-tech" engineering, but in their management and production techniques.

Productivity very definitely depends upon organization and can be increased with

a) Systematic planning and production engineering before production starts

b) Detailed monitoring of production progress

c) Regular feedback of results to ensure continual improvement in planning and control

d) Informed and resourceful management that can implement changes wherever and whenever needed

Ship production is complex and requires an interlinking of many plans and requirements. And while many shipyards pride themselves on their ability to plan, they too often do not apply sufficient resources and proper tools to do the job properly. What results is a production "plan" that does not coordinate the various participants of the project, and the ensuing confusion not only increases current production costs but also obscures exciting new cost and schedule savings opportunities for future work.

The planning effort, therefore, should focus upon not only how best to maintain cost and schedule today, but also how to continually refine this planning process so that costs can steadily be driven downward and schedules shortened. This feedback loop obviously requires an ability to bring together ("integrate") all requirements for manpower, schedule, and material.

The ship design, planning and management efforts must concentrate together and find new ways to make ships easier and faster to build.

This process, to its conclusion, will enable today's shipyard to be considerably more competitive tomorrow.

## 3.0 THE INTEGRATED SYSTEMS SOLUTION

Small and medium sized shipyards are now gaining sizeable benefits from applying more efforts to planning and production engineering. These areas form the foundation by which shipyard resources (manpower, facilities and material) can be successfully coordinated. The advent of the inexpensive mini-computers and software systems available have augmented these efforts so that the coordination ("integration") of the various areas of the shipyard can be assured, monitored and controlled to best advantage.

The system uses a multiple module philosophy in which all modules are interconnected under user control, or can be run independently for specific application. The main modules are referred to by their trade names of PERT-PAC, WORK-PAC, and MAT-PAC.

PERT-PAC: A job scheduling system based upon the critical path method and enhanced by specialized techniques for automating network updates and re-scheduling. PERT-PAC's Micronet library functions reduce planning time and improve network data accuracy.

WORK-PAC: A production labor planning and control system based upon the work package concept, employing statistical techniques for automating job progress and final total cost projections on a continuous basis.

MAT-PAC: An interactive material requirements planning, purchasing and delivery control system designed to expedite project material planning and procurement.

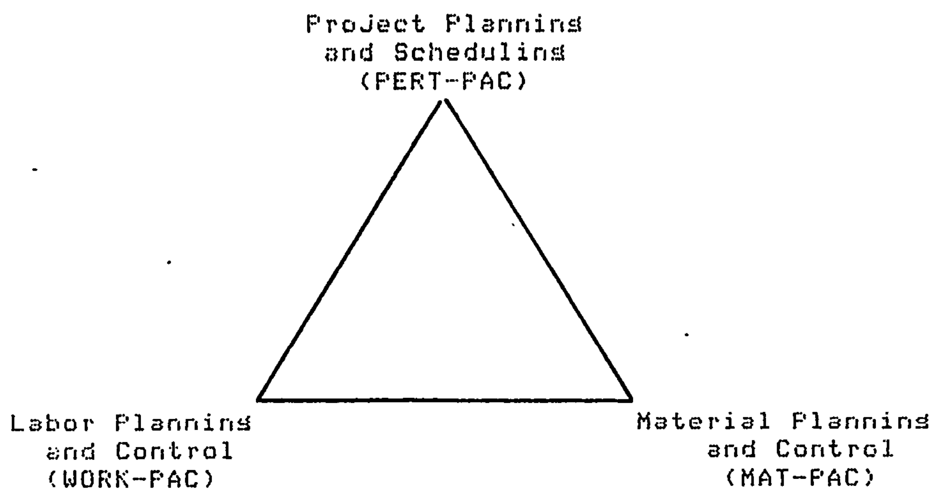



FIGURE 3.0.1

Integrated Project Planning & Management Control System Triad

## 3.1 PLANNING & PRODUCTION ENGINEERING

The planning and production engineering processes must be tied together and both require a certain amount of lead time to be successful. During this time the design process must examine and evaluate various techniques that best exploit the production process:

a) Techniques which allow more extensive application of production engineering procedures in the time available - however short. These are concerned with digesting general experience to improve producibility through more and better standardization in the yard.

b) Techniques which themselves reduce the necessity for lead time. These are mainly concerned with the application of computer methods to the design development and production information processes.

c) Techniques which maximize production efficiency. For example, the pre-assembling of material items in the shop environment is often significantly less expensive than if the assembly were done at the job site (i.e., on board ship). Not only is there less opportunity for adding to costs from extra crew transfers and gathering together all needed equipment and materials at remote locations, but also climatic conditions and personnel morale within the production environment can bear heavily upon the ultimate cost of the effort.

The lead time requirement is a product of the level of technology employed and the balances chosen within total contract execution. In making the transition to longer lead times, the demands of the orderbook will be a dominant factor in order to achieve continuity of production. This implies a phasing of the implementation of planning and production engineering procedures to suit each individual yard for the given occassion.

Procedures, particularly those relating to geometry and block breakdown, do not of themselves affect lead time significantly. Other procedures, particularly equipment and ship module techniques, do require an investment both in time and manpower to realize the potential benefits. In these cases it is necessary to review and define the extent of implementation.

The planning and production engineering processes must be supported by an organizational structure and sound operational procedures to assure adequate feedback from the production facilities to the Drawing Office for up-dating and validating of drawings.

## 3.2 SCHEDULING

The preliminary planning for the project is based upon detail knowledge of the shipyard resources, contract specifications, the general arrangement drawings, mile-stone target dates and shipyard holiday schedule.

The project schedule is developed with a critical path network. Standardized planning modules, called Micro-nets, are developed for various stages of the project. Data collected by the planners include the steel erection sequence, equipment lists and related foundations, and preliminary plans ("ideas") for zone outfitting, modularization and unit pre-outfitting.

The successful execution of the network schedule depends upon a numbering system where a unique number for each segment of the network is assigned and cataloged. The vessel is sectioned into manageable zones and units with discrete identification numbers which remain unchanged throughout the project. Developing the project network is an evolutionary process. The stages for the project are as follows:

a) Review the Master Schedule

b) Develop network plans and options

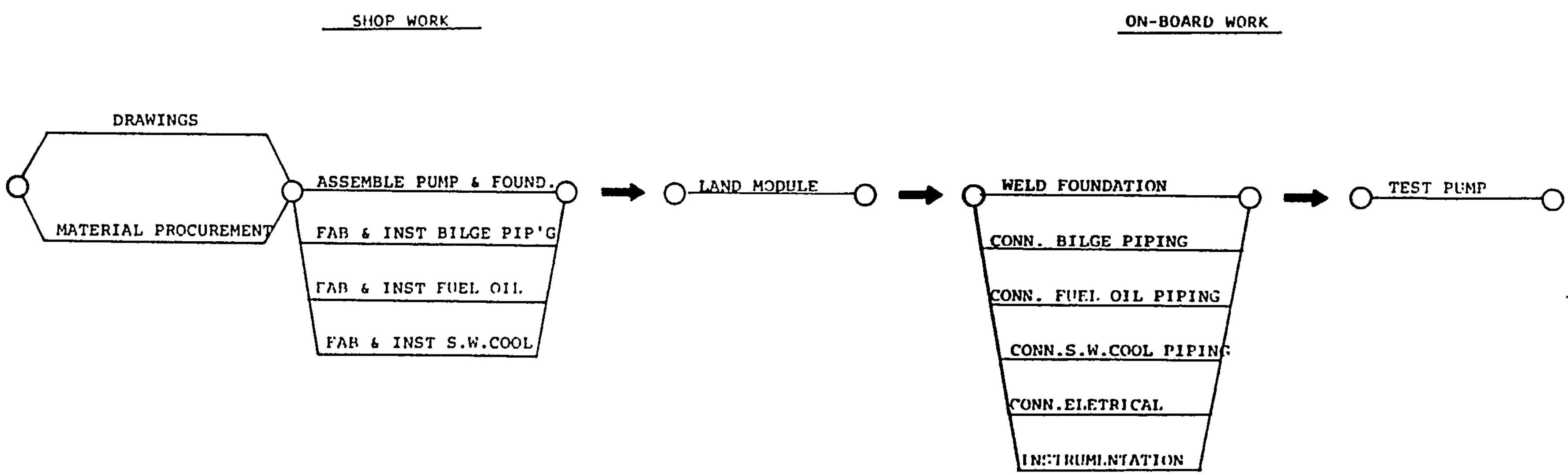
c) Develop the steel Micronets detailing all activities for a steel unit from drawings, material procurement, through fabrication and assembly, and finally erection and finish welding

d) Build the network by transferring all steel unit Micronets and linking them at erection in their natural sequence

e) Build and install erection and/or assembly constraint dummy activities to ensure unit erection sequence is correct (for example, deck units cannot be erected until side units are in place)

FIGURE 3.1.1:
Sample Multiple Ship System Outfit Module

# OUTFIT MODULE
# Salt Water Circulating Pump



f) Provide broad-scale zone outfit activities that are brought together for zone and system tests

d) Install sea trials and delivery activities

h) Revise and refine milestones for summary overview purposes

i) Set start-off link activity to begin erection on anticipated start date

j) Process network, review milestone schedules, approve the erection sequence, and plot the erection sequence

k) Develop equipment module Micronets complete with durations, link to all procurement as appropriate

1) Transfer equipment module Micronets to network

m) Develop main machinery installation sequence complete with drawings and material procurement activities

n) Develop zone outfitting Micronets complete with drawings and material procurement

0) Develop unit pre-outfitting Micronet complete with drawings and material procurement

P) Develop tank and systems' testing Micronets

q) Transfer Micronets to network. Process and review.

The Plan Schedules undergo two discrete phases of development before being fully usable by Production. These are

a) Network planned schedules

b) Resource loaded schedules

Network planned schedules reflect dates as directly generated by the PERT-PAC Main Processor and represent the most attainable dates limited only by the activity sequences. Network planned schedules can be obtained at any time during the developmental phase of the network and are used to validate the overall sequence of work represented by the network.

FIGURE 3.2.1:
Sample Steel Assembly Micronet

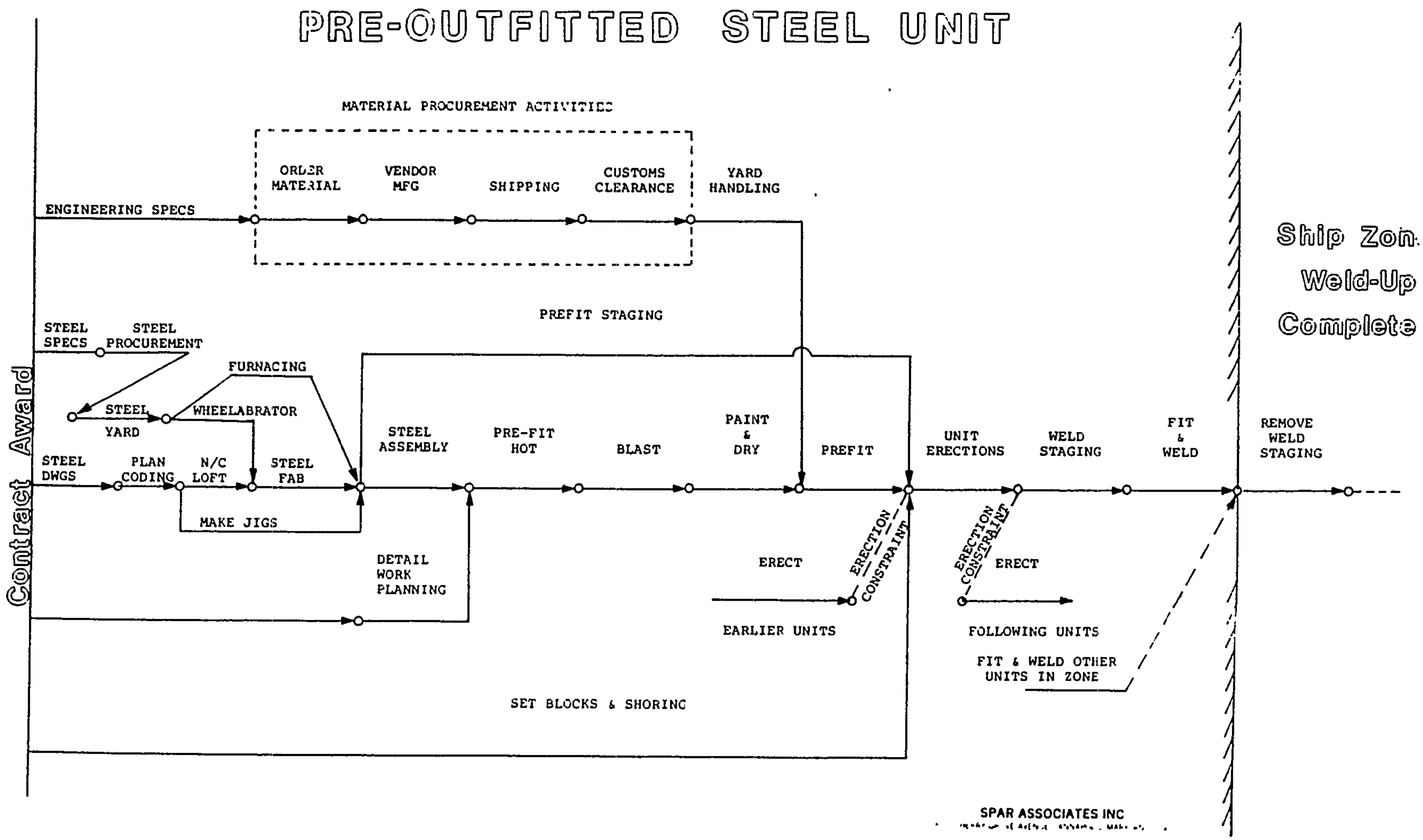


FIGURE 3.2.2:
Sample Accommodations Micronet

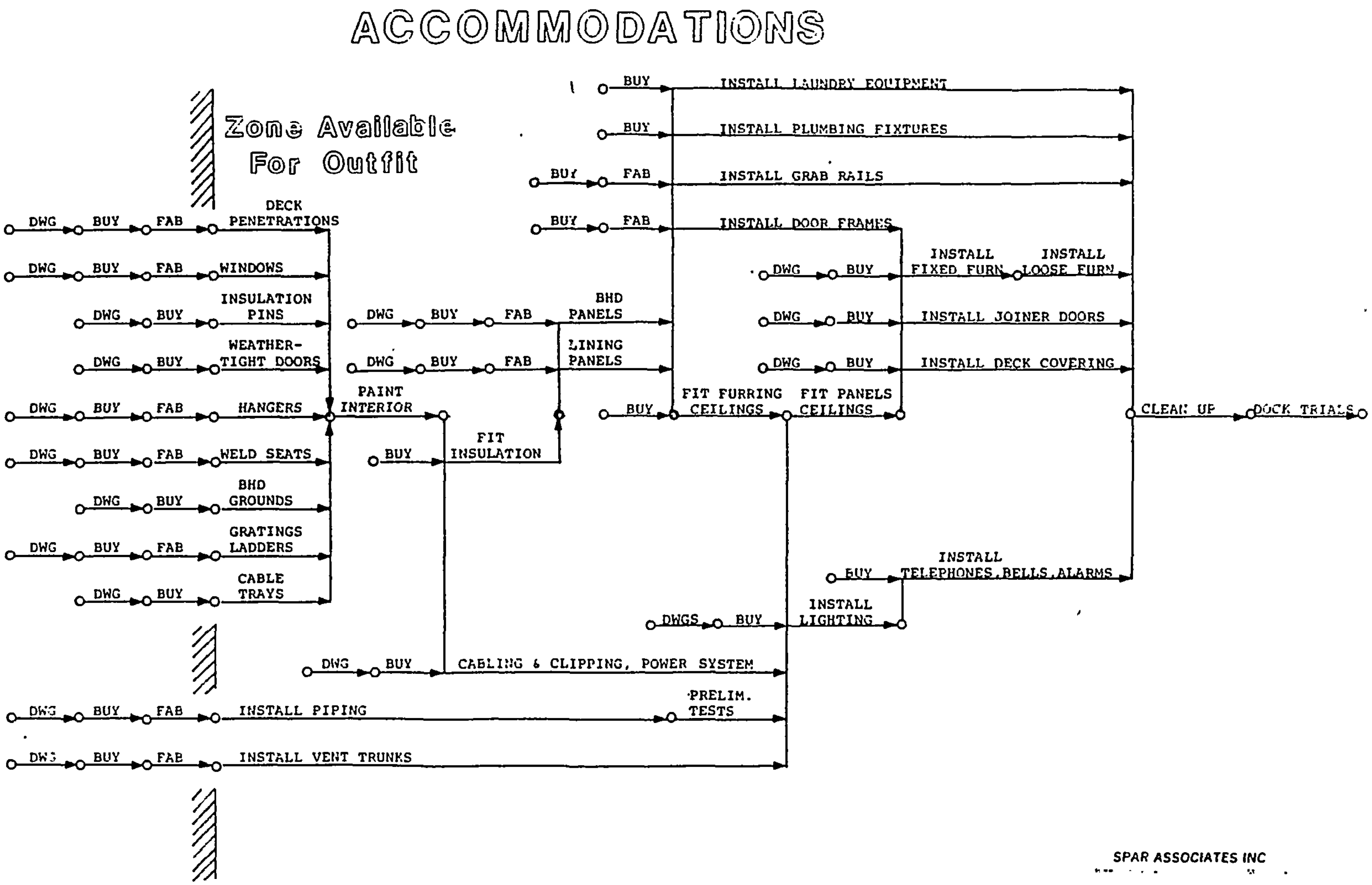
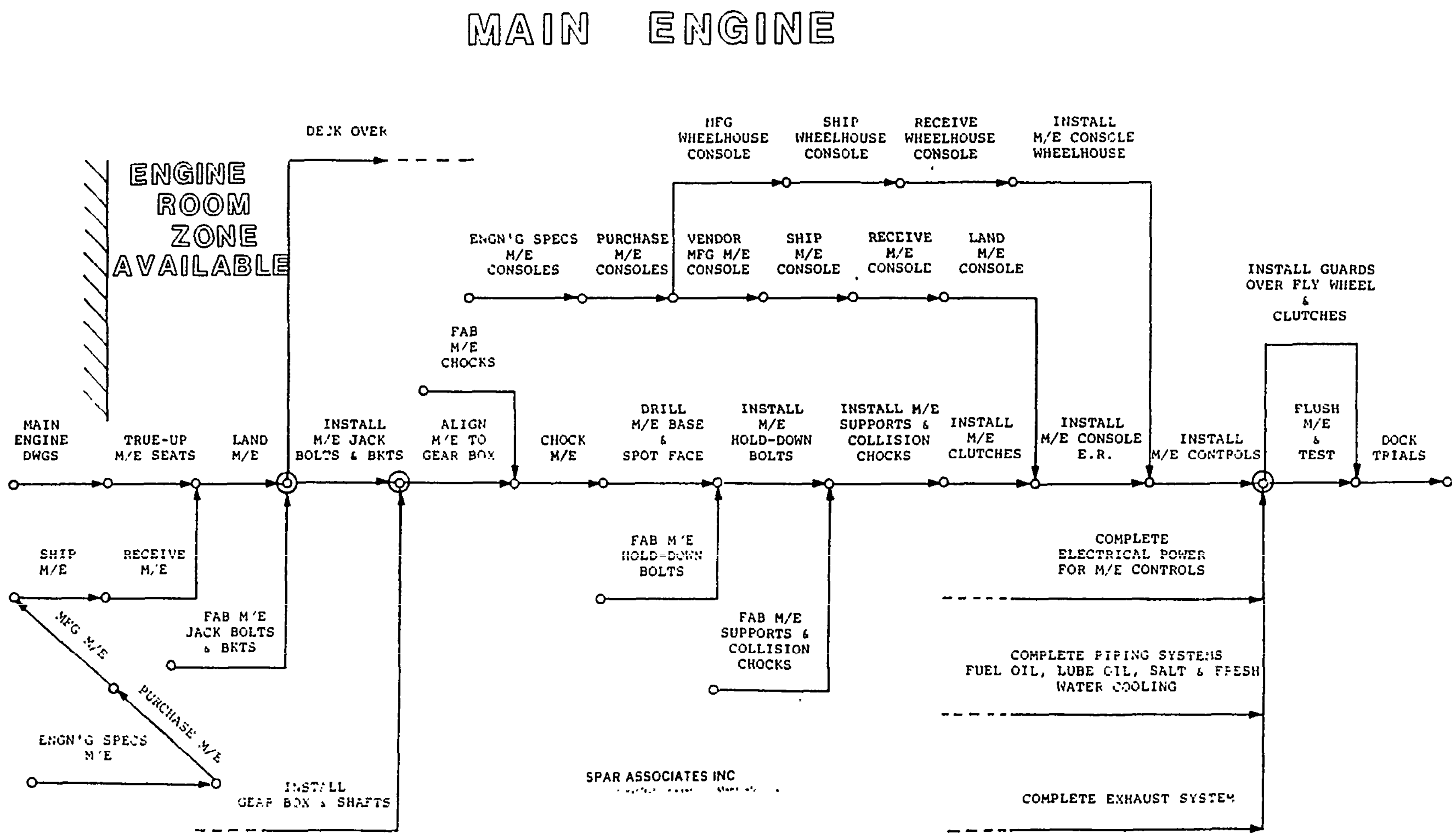


FIGURE 3.2.3:
Sample Machinery Systems Micronet



Resource loading allows specific restrictions of available resources (manpower, floor space, etc.) to influence the schedules further.

Resource loading normally is not applied until the network is generally complete and the correct work sequencing fully established. The loading process entails determining budgets, steel unit sizes (for floor space restrictions, etc.), facilities and manpower availabilities. Resource loading is done using either the PERT-PAC Allocator subsystem or the WORK-PAC Manpower subsystem. Both methods accomplish the same result, except that the Allocator does handle non-labor resources, while Manpower cannot. Results from the resource Loadings, including revised schedules, are transferred back to the network from either subsystem.

## 3.3 LABOR PLANNING AND CONTROL

Shipyard management has a continuous need to measure work progress and manhour performance so that any problems that develop hopefully can be remedied before they become critical.

Most shipyards manually assess physical progress and this approach always depends entirely upon an individual's interpretation of the progress and is therefore highly subjective. Manual assessments also cost considerable time and effort.

WORK-PAC is a computer system that 'measures progress and makes final manhour cost projections objectively and continuously based upon actual statistically-derived productivity information continuously being supplied to the system. WORK-PAC further summarizes performance trends not only by the project work breakdown structure, but by the shipyard's organization structure (work centers, departments, and trades) as well. This visibility is valuable not only to planning management, but also to production control supervisors.

The WORK-PAC manpower planning and control procedures are developed using the work package concept throughout:

a) New ship construction

b) Ship repair projects

c) Commercial engineering projects

d) Shipyard maintenance and overhead work

Cost Accounts (WBS or engineered ship systems) require contributions of effort from many areas of the shipyard organization (see Figure 3.3.1 for an illustration of a logical distribution and sequencing of work effort). Each of these separate and distinct efforts form the basis of the work package scheme for an account and are fairly easy to establish since they provide the fundamental plan by which the project shall be executed, REGARDLESS OF BUDGET, SCHEDULE, OR EVEN ENGINEERING DETAILS.

The work package represents a distinct and definable unit of work that starts and completes ideally without significant interruption, under the direction of a single authority or work center. The scope of work can be clearly identified, and the work package can be budgeted and scheduled.

Work packages are developed precisely in the manner consistent with the way shipyard production will perform the work. Production will normally accomplish its effort as a logical set of steps; the work package, while including a selected number of these steps, will be so defined to correlate directly with appropriate tasks and operations.

The approaches of pre-outfitting, modularization (outfit on block) and mass production techniques all are attempts to make the most of available resources with minimum attending costs. The labor planning and control system, WORK-PAC, provides a convenient means to develop work packages that support these efforts WITHOUT altering the basic work breakdown structure for cost budgeting and actual cost collection. These production techniques are not the result of any dramatic change in planning or production philosophies or even in the structuring of the project's chart of accounts, but merely upon the re-ordering of work according to a better scheduling approach. Indeed, scheduling does have a definite bearing upon the cost of any endeavor.

Work packages are developed so that when completed, there is a clear track as to precisely what has been accomplished. Further, WORK-PAC summarizes work package performance and provides performance trend information valuable for continued production monitoring and control.

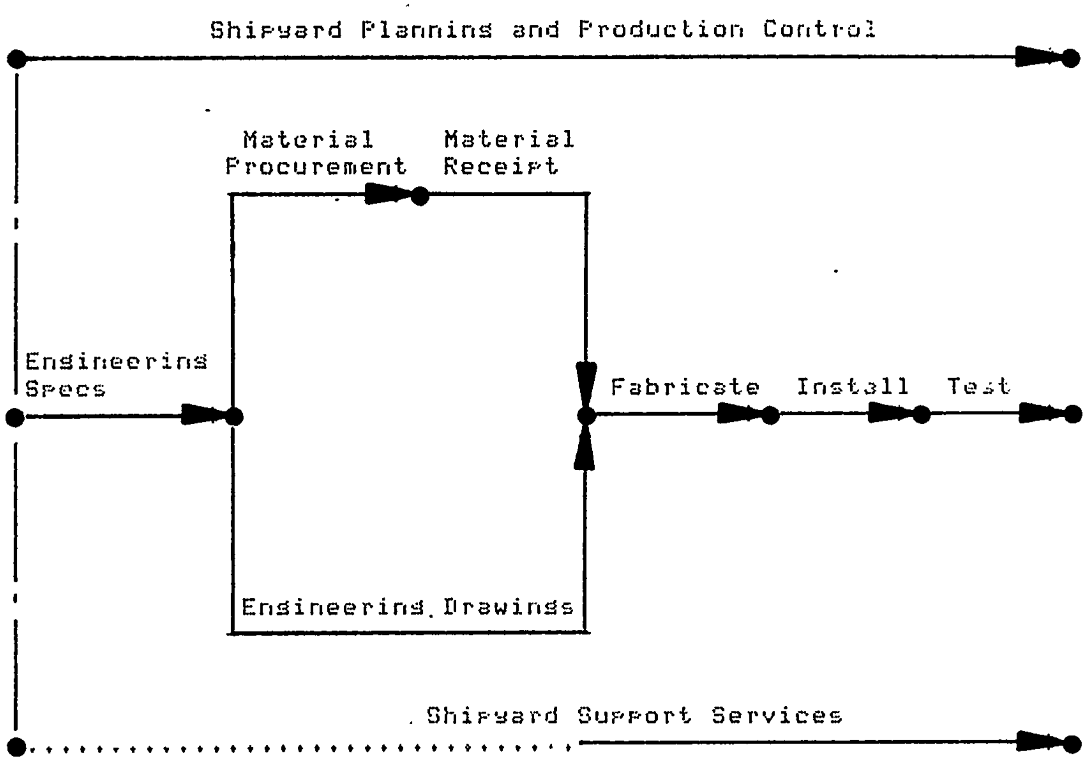



FIGURE 3.3.1: Basic Identification Of Ship System (Cost Account) Work Packages

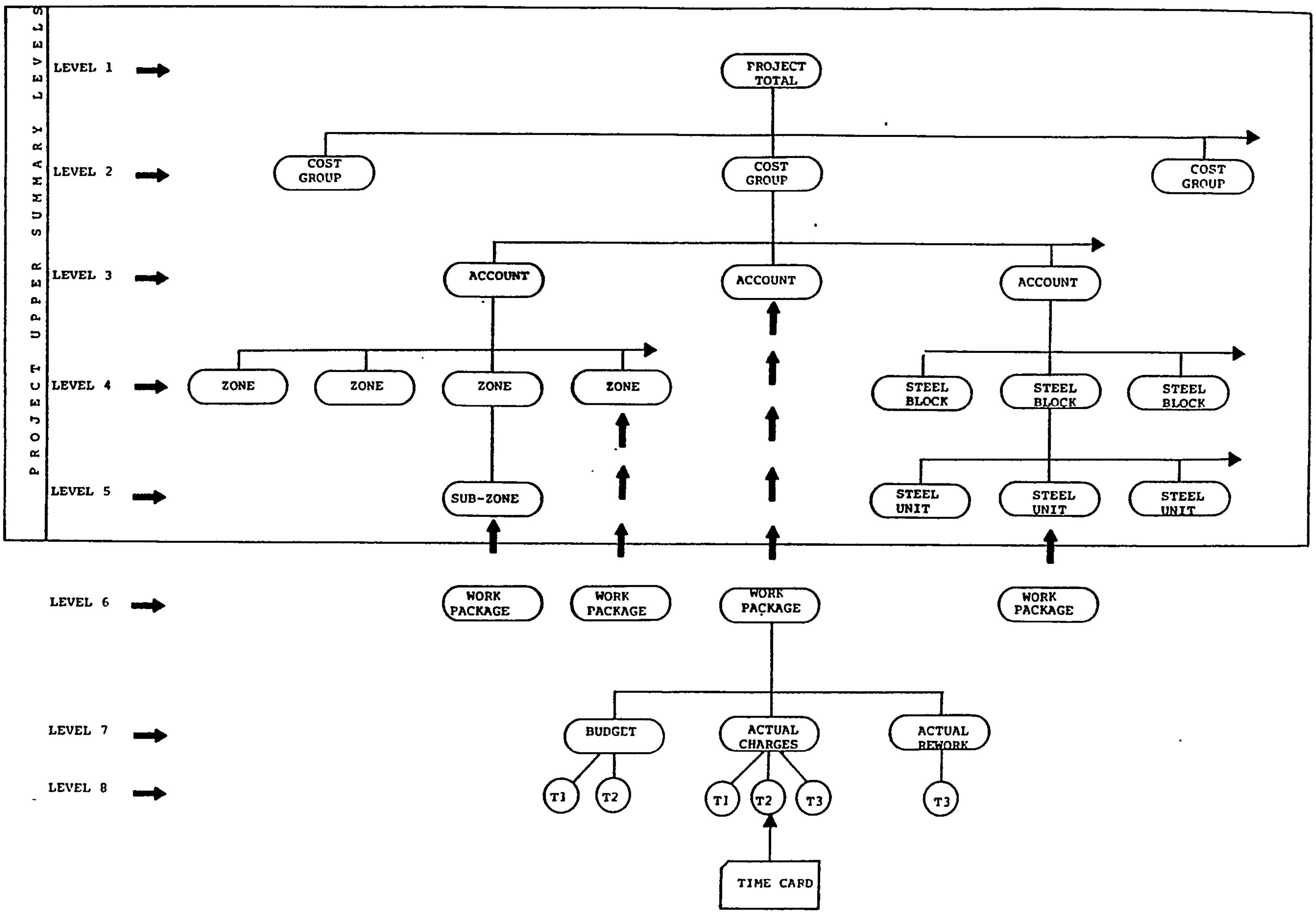



FIGURE 3.3.2:
Labor Planning & Control System Work Breakdown Structure

REPORT (21.2) 1001 1000 FT TEST SHIP 25AUG79

COST PERFORMANCE REPORT - WORK BREAKDOWN STRUCTURE
PROJECT SUMMARY

| WBS | CURRENT PERIOD SINCE 18AUG79 BCWS | BCWP | ACWP | SCHED VAR | COST VAR | CUMULATIVE TO DATE BCWS | BCWP | ACWP | SCHED VAR | COST VAR | AT COMPLETION BUDGET | EAC | VARIANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 16638. | 11287. | 15544. | -5351. | -4257. | 203002. | 189324. | 190631. | -13618. | -1247. | 471566. | 474670. | -3104. |
| 1 | 121. | 331. | 265. | 210. | 66. | 650. | 1350. | 1281. | 700. | 69. | 54182. | 51412. | 2770. |
| 2 | 980. | 704. | 708. | -276. | -4. | 7761. | 4696. | 4650. | -3065. | 46. | 53980. | 53450. | 530. |
| 3 | 928. | 934. | 995. | 6 | -61. | 7828. | 8707. | 8909. | 879. | -102. | 82250. | 83216. | -966. |
| 4 | 1484. | 1705. | 1717. | 221. | -11. | 17420. | 8339. | 8318. | -9081. | 22. | 79608. | 79402. | 206. |
| 5 | 451. | 360. | 361. | -92. | -1. | 1943. | 804. | 804. | -1139. | 0. | 27662. | 27661. | 1. |
| 6 | 691. | 148. | 149. | -543. | -1. | 1990. | 310. | 310. | -1679. | -0. | 57419. | 57420. | -1. |
| 7 | 1875. | 1. | 2217. | -1874. | -2216. | 41210. | 33328. | 31461. | -7882. | 1867. | 124426. | 120243. | 4183. |
| 8 | 267. | 47. | 57. | -220. | -10. | 6832. | 1410. | 1432. | -5422. | -21. | 15123. | 15353. | -230. |
| 9 | 595. | 208. | 279. | -387. | -71. | 19792. | 22117. | 22117. | 2325. | 0. | 33784. | 33784. | 0. |
| SUB TOTAL | 24029. | 19942. | 22289. | -4087. | -2346. | 308427. | 270724. | 269807. | -37703. | 917. | 1000000. | 996612. | 3388. |
| MANAGEMENT RESERVE | | | | | | | | | | | 60000. | | 60000. |
| TOTAL DIRECT LABOR | | | | | | | | | | | 1060000. | 996612. | 63388. |

WBS = WORK BREAKDOWN STRUCTURE (GROUP OR COST NO.)
BCWS = BUDGETED COST (MANHRS) OF WORK SCHEDULED TO-DATE
BCWP = BUDGETED COST (MANHRS) OF WORK PERFORMED TO SAME PROGRESS TO-DATE
ACWP = ACTUAL COST (MANHRS) OF WORK PERFORMED TO-DATE
SCHED.VAR. = SCHEDULE VARIANCE (MANHRS) BETWEEN WHAT PLANNED AND WHAT WAS ACTUAL FOR CURRENT PROGRESS (BCWP-BCWS)
COST VAR. = COST (MANHRS) VARIANCE TO-DATE (BCWP-ACWP)
EAC = ESTIMATED (MANHR COST) AT COMPLETION

NEGATIVE VARIANCES INDICATE COST OVER-RUN OR SCHEDULE SLIPPAGE

FIGURE 3.3.3:
Sample WORK-PAC C/SCS Performance Report
(WBS Cost Group Summary)

REPORT (23.) 1001 1000 FT TEST SHIP 25AUG79

COST PERFORMANCE REPORT - WORK CENTER BREAKDOWN
PROJECT SUMMARY

| | | CUMULATIVE TO DATE | | | | | AT COMPLETION | | |
|---|---|---|---|---|---|---|---|---|---|
| AREA | | BCWS | BCWP | ACWP | SCHED VAR | COST VAR | BUDGET | EAC | VARIANCE |
| 1 | STEEL FAB SHOP | 37693. | 33041. | 31988. | -4652. | 1053. | 78035. | 75549 | 2486. |
| 2 | STEEL SUB-ASSEMBLY SHOP | 101826. | 97203. | 96577. | -4624. | 625. | 133079. | 131837. | 1242. |
| 3 | STEEL ERECTION ON WAYS | 18972. | 17084. | 16217. | -1888. | 867. | 66200. | 64243. | 1957 |
| 4 | WELDING ON-SHIP | 22411. | 23349. | 26185. | 938. | -2835. | 91271. | 102354. | -11083. |
| 5 | N/C | 11120. | 11236. | 9657. | 115. | 1579. | 11892. | 10221. | 1671. |
| 6 | EXPEDITING | 11136. | 9847. | 9414. | -1289. | 433. | 27027. | 25838. | 1189. |
| 7 | CENTRAL PLANNING | 9381. | 8021. | 6929. | -1360. | 1092. | 20506. | 19174 | 1332. |
| 9 | ENGINEERING & DESIGN | 19792. | 22117. | 22117. | 2325. | 0. | 33785. | 33785. | 0. |
| 10 | PRODUCTION SERVICES | 25017. | 15753. | 15463. | -9264. | 290. | 85792. | 84300. | 1492. |
| 11 | MISCELLANEOUS SHIP STEEL | 10980. | 10069. | 10013. | -911. | 56. | 31722. | 31546. | 176. |
| 15 | MISCELLANEOUS SERVICES | 3514. | 777. | 1088. | -2737. | -311. | 6223. | 7043. | -820. |
| 21 | OUTFIT ACCOMODATIONS - SHOPS | 175. | 96. | 96. | -79. | 0. | 23274. | 23274. | 0. |
| 22 | OUTFIT CARGO SYSTEMS - SHOPS | 3489. | 1914. | 1914. | -1575. | -0. | 20066. | 20066. | 0. |
| 23 | OUTFIT MECHANICAL - SHOPS | 2546. | 2305. | 2327. | -240. | -22. | 24774. | 25010. | -236. |
| 24 | PIPE SHOP | 6282. | 3556. | 3556. | -2725. | 0. | 32091. | 32091. | 0. |
| 25 | MACHINE SHOP | 1013. | 269. | 269. | -744. | 0. | 11061. | 11061. | 0. |
| 26 | ELECTRICIANS SHOP | 753. | 0. | 0. | -753. | 0. | 17867. | 17867. | 0. |
| 31 | OUTFIT ACCOMODATIONS - SHIP | 475. | 1185. | 1185. | 710. | 0. | 30900. | 30900. | 0. |
| 32 | OUTFIT CARGO SYSTEMS - SHIP | 4272. | 2736. | 2736. | -1535. | 0. | 33912. | 33912. | 0. |
| 33 | OUTFIT MECHANICAL - SHIP | 5282. | 6481. | 6481. | 1199. | 0. | 57475. | 57475. | 0. |
| 34 | PIPING - ON SHIP | 11139. | 4761. | 4761. | -6377. | 0. | 47530. | 47530. | 0. |
| 35 | MACHINISTS - ON SHIP | 930. | 535. | 535. | -395. | 0. | 16604. | 16604. | 0. |
| 36 | ELECTRICIANS - ON SHIP | 1236. | 310. | 310. | -926. | 0. | 39553. | 39553. | 0. |
| SUB TOTAL | | 309433. | 272646. | 269820. | -36787. | 2826. | 1000639. | 1001231. | -592. |

| | BUDGET | EAC | VARIANCE |
|---|---|---|---|
| UNDISTRIBUTED BUDGET | -639. | -639. | |
| PROJECT ADJUSTMENTS | | -3980. | 3980. |
| SUB-TOTALS | 1000000. | 996612. | 3388. |
| MANAGEMENT RESERVE | 60000. | | 60000. |
| TOTAL DIRECT LABOR | 1060000. | 996612. | 63388. |

WBS = WORK BREAKDOWN STRUCTURE (GROUP OF COST NO.)
BCWS = BUDGETED COST (MANHRS) OF WORK SCHEDULED TO-DATE
BCWP = BUDGETED COST (MANHRS) OF WORK PERFORMED TO SAME PROGRESS TO-DATE
ACWP = ACTUAL COST (MANHRS) OF WORK PERFORMED TO-DATE
SCHED.VAR. = SCHEDULE VARIANCE (MANHRS) BETWEEN WHAT PLANNED AND WHAT WAS ACTUAL FOR CURRENT PRO-GRESS (BCWP-BCWS)
COST VAR. = COST (MANHRS) VARIANCE TO-DATE (BCWP-ACWP)
EAC = ESTIMATED (MANHR COST) AT COMPLETION

NEGATIVE VARIANCES INDICATE COST OVER-RUN OR SCHEDULE SLIPPAGE

FIGURE 3.3.4:
Sample WORK-PAC C/SCS Performance Report
(Work Centers)

REPORT (22.) 1001 1000 FT TEST SHIP 25AUG79

COST PERFORMANCE REPORT - TRADE BREAKDOWN
PROJECT SUMMARY

| TRADE | | CUMULATIVE TO DATE | | | | | AT COMPLETION | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BCWS | BCWP | ACWP | SCHED VAR | COST VAR | BUDGET | EAC | VARIANCE |
| 1 | AIR TOOL ROOM | 683. | 222. | 233. | -461. | -11. | 4899. | 4909. | -11. |
| 2 | BLACKSMITHS | 530. | 774. | 925. | 245. | -151. | 2928. | 3340. | -412. |
| 4 | PLANT MAINTENANCE | 0. | 0. | 7. | 0. | -7. | 0. | - | -7. |
| 5 | BURNERS | 22314. | 21856. | 21919. | -458. | -63. | 56922. | 57037. | -115. |
| 6 | CARPENTERS - SHIP | 10246. | 10390. | 10310. | 144. | 80. | 47743. | 47339. | 405. |
| 7 | CHIPPERS & CAULKERS | 4290. | 3410. | 2278. | -881. | 1132. | 14435. | 14131. | 305. |
| 8 | CRANEMEN | 6859. | 7165. | 7220. | 306. | -55. | 20270. | 20332. | -61. |
| 9 | DRILLERS & REAMERS | 35. | 27. | 54. | -8. | -27. | 682. | 709. | -27. |
| 10 | ELECTRICIANS | 4590. | 1295. | 1336. | -3295. | -41. | 59804. | 59845. | -41. |
| 11 | FITTERS | 32295. | 30054. | 29558. | -2241. | 496. | 66322. | 65152. | 1170. |
| 13 | FURNACEMEN - SLAB | 1485. | 1420. | 1433. | -65. | -13. | 1662. | 1675. | -13. |
| 14 | JOINERS | 631. | 557. | 564. | -74. | -7. | 35135. | 35142. | -7. |
| 15 | LABOURERS | 4100. | 3022. | 3010. | -1078. | 12. | 29169. | 28994. | 175. |
| 16 | MACHINISTS | 2837. | 4843. | 4884. | 2007. | -40. | 16122. | 16162. | -40. |
| 17 | MOULD LOFT | 12148. | 11780. | 10218. | -368. | 1562. | 12446. | 10795. | 1650. |
| 18 | PAINTERS | 2077. | 2218. | 2267. | 141. | -49. | 19862. | 20140. | -278. |
| 21 | PIPE FITTERS | 9300. | 2681. | 2710. | -6619. | -28. | 32797. | 32826. | -28. |
| 22 | PLUMBERS | 1457. | 8. | 19. | -1449. | -11. | 24216. | 24227. | -11. |
| 23 | POWER HOUSE | 0. | 0. | 3. | 0. | -3. | 0. | 3. | -3. |
| 24 | PUNCH SHED | 7213. | 6224. | 5384. | -989. | 840. | 13164. | 11293. | 1871. |
| 25 | RIGGERS | 10547. | 8067. | 7065. | -2480. | 1001. | 35039. | 34174. | 866. |
| 27 | SHEET METAL WORKERS | 327. | 471. | 484. | 144. | -12. | 12196. | 12208. | -12. |
| 28 | STAGE BUILDERS | 4269. | 3324. | 3308. | -946. | 15. | 22743. | 22575. | 169. |
| 29 | STOCKYARD - STEEL | 4427. | 4993. | 6651. | 566. | -1658. | 10127. | 13489. | -3362. |
| 30 | STORESMEN | 3596. | 3146. | 2330. | -450. | 816. | 8681. | 8131. | 550. |
| 31 | TRUCK DRIVERS | 2615. | 2100. | 1412. | -515. | 689. | 7969. | 7724. | 245. |
| 33 | WELDERS - ELECTRIC | 79365. | 68672. | 68650. | -10693. | 21. | 231000. | 230143. | 857. |
| 34 | NIGHT FOREMEN | 121. | 32. | 81. | -88. | -48. | 270. | 319. | -48. |
| 35 | PREPARATION FITTER | 15184. | 16362. | 15856. | 1178. | 506. | 27186. | 26292. | 895. |
| 36 | SHIP FITTERS | 9917. | 6594. | 5098. | -3323. | 1496. | 45011. | 44570. | 441. |
| 37 | MACHINISTS - OS | 2857. | 1526. | 1547. | -1331. | -22. | 26223. | 26245. | -22. |
| 38 | INDUST.ENGINEER | 0. | 0. | 89. | 0. | -89. | 0. | 89. | -89. |
| 40 | DRAWING OFFICE | 19791. | 22117. | 22117. | 2326. | 0. | 33784. | 33784. | 0. |
| 41 | PLANNING | 6290. | 6172. | 6246. | -118. | -74. | 13750. | 13915. | -165 |
| 42 | QUALITY CONTROL | 3091. | 2643. | 669. | -448. | 1974. | 6757. | 6564. | 192. |
| 99 | WELDERS - TACKING | 18924. | 21260. | 23886. | 2336. | -2626. | 47587. | 50801. | -3214. |
| SUB TOTAL | | 304413. | 275427. | 269820. | -28987. | 5606. | 986900. | 985077. | 1823. |

| | BUDGET | EAC | VARIANCE |
|---|---|---|---|
| UNDISTRIBUTED BUDGET | 13100. | 13100. | |
| PROJECT ADJUSTMENTS | | -1565. | 1565 |
| SUB-TOTALS | 1000000. | 996612. | 3388 |
| MANAGEMENT RESERVE | 60000. | | 60000 |
| TOTAL DIRECT LABOR | 1060000. | 996612. | 63388 |

FIGURE 3.3.5:
Sample WORK-PAC C/SCS Performance Report
(Trades)

## 3.4 MATERIAL PLANNING AND CONTROL

The material control problem for shipyards dealing with large-scale projects is far different and more complex to solve than that for manufacturing companies producing quantities of like products.

Shipyards manufacture essentially one-off products, each customized to suit a given contract. The material requirements, therefore, are largely specific to the contract, specially purchased and individually expedited to keep pace with production. Inherently, this places a premium emphasis upon the scheduling of this material procurement process. Furthermore, the high cost of material storage and handling and the recent high costs of financing stock inventories have made direct purchasing of material far more necessary than was the case years past. Now there is little room to ignore delivery problems, since the shipyard has virtually no chance to make up for any delays or losses with a subsequent production run. A shipyard must be successful on each and every vessel, or face severe financial difficulties. And the pressure of shipyards competing against one another under limited marketing opportunities requires that a successful yard offer not only a less expensive ship, but also one that can be built faster than the competition.... and too often faster than the declines of the financial markets, which can quickly dry up a ship order before the keel is laid.

MAT-PAC is fully integrated with the scheduling system, PERT-PAC. This helps ensure that the material procurement and delivery functions meet the needs of production with minimium difficulties. PERT-PAC develops the schedules which incorporate not only constraints by production, but also those in other areas, including engineering and material. In response, MAT-PAC updates PERT-PAC with current delivery status so that any delays can be analyzed directly and their impact upon production measured. PERT-PAC keeps track of all schedules and provides a convenient means to coordinate all efforts and ensure that management focuses its attention mostly upon high-priority problems.

MAT-PAC permits material to be purchased directly for a given project, and from stock inventories. While most other material systems accommodate the latter,the direct purchase problems are rarely addressed adequately for the shipyard environment. Further, the scheduling features of MAT-PAC provide a means to determine WHEN scheduled contract demands upon stocks require re-ordering. Again, the importance of the scheduling cannot be overstated. This visibility of future material requirements

not only ensures that production needs are satisfied both today and tomorrow, but also that opportunities for reduced costs possible from bulk buying can be better exploited.

MAT-PAC permits material requirements to be fully defined by detail requisitions. However, shipbuilding is often known to begin the material purchasing functions long before actual engineering drawings and bills of material are available. MAT-PAC provides this necessary flexibility without losing control of the procurement process.

Since schedules are so important, MAT-PAC provides a strong capability to ensure requests for quotations ("RfQs") are issued and supplier responses received on a timely basis. The system also sets schedules for ensuring timely issuing of subsequent purchase orders and their acknowledgements by suppliers. MAT-PAC further provides a capability to input and store a full set of material specifications (text information) with requisitions and purchase orders. Once done, many requisitions can be "copied" to future contracts with little change; this reduces manual processing time significantly.

In fact, the copying features of the system even provide the user with simple escalation factors that may be applied to old cataloged prices. This powerful capability not only generates more quickly a complete set of detail material requirements for a new contract, but also a faster material cost estimate. The system easily rolls up new detail estimates to the ship work breakdown structure of cost accounts for summary review.

MAT-PAC has a comprehensive material delivery expediting capability that enables material procurement personnel to concentrate more on critical problems and less upon the non-essential ones.

MAT-PAC has been designed to perform in the real world of a shipyard. It easily handles such problems as fluctuating foreign exchange rates, suppliers that act through brokers, and forecasts cash flow needs for import payments.

MAT-PAC also accommodates such un-planned problems as intra-contract material transfers, which inevitably occur when one contract finds itself short of needed material.

MAT-PAC provides immediate reporting of actual costs against planned budgets. Linked with WORK-PAC, the system generates a full summary of labor and material costs by the familiar ship work breakdown structure.

FIGURE 3.4.1:
Material Planning & Control System Work Breakdown Structure

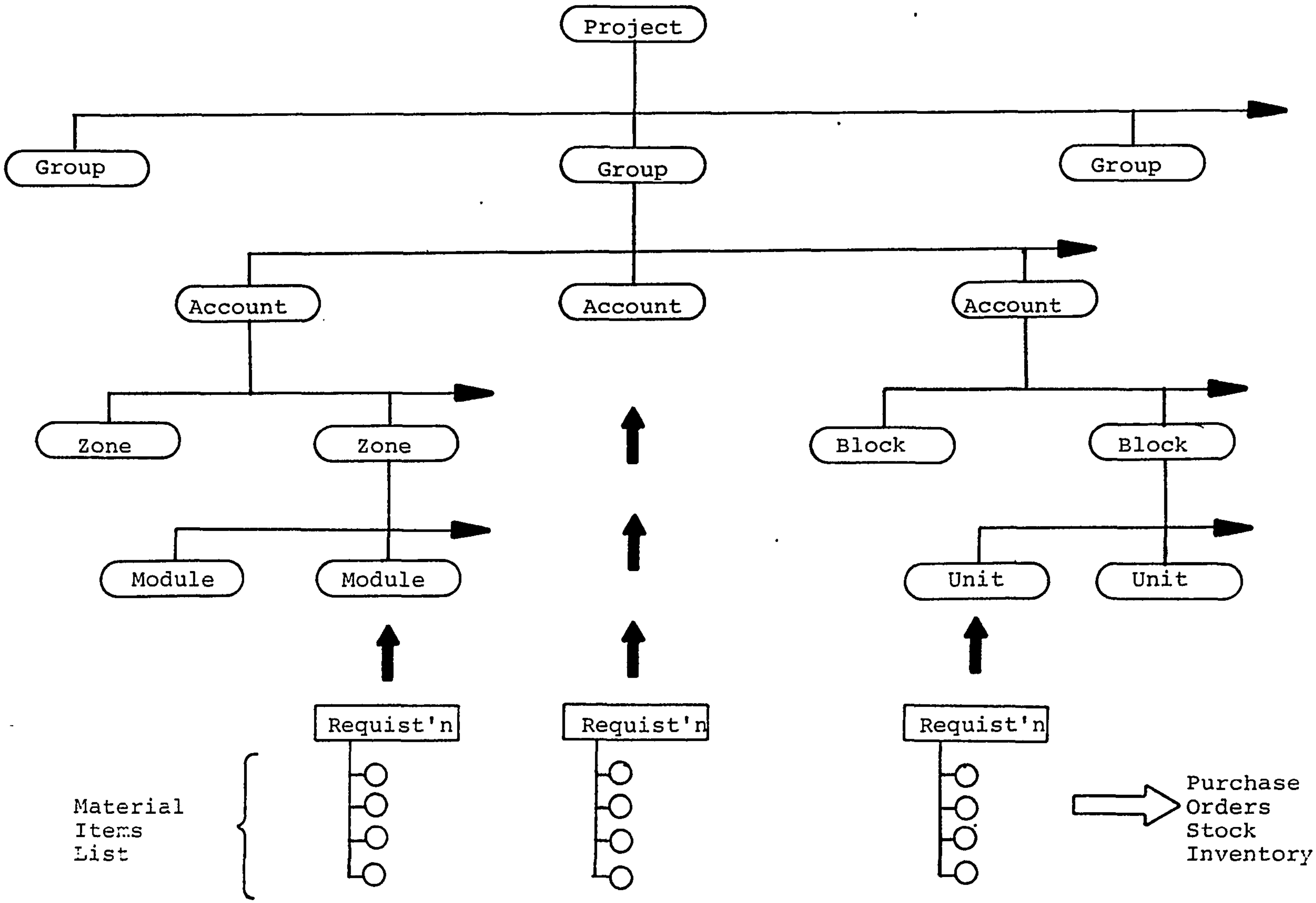


FIGURE 3.4.2:
Sample MAT-PAC C/SCS Performance Report (WBS)

MATERIAL COST PERFORMANCE REPORT

[illegible]ECT: 450. TEST SHIP
[illegible]YSIS DATE: 23AUG82

(Dollars X 1000)

| COST ACCT | BCMS | BCMU | ACMU | SCHED VAR | BUDGET VAR | TOTAL BUDGET | MEAC | MEAC VAR |
|---|---|---|---|---|---|---|---|---|
| 100. | 12589. | 11254. | 11254. | 1335. | 0. | 15245. | 15245. | 0. |
| 102. | 13588. | 900. | 900. | 12688. | 0. | 14000. | 14000. | 0. |
| 109. | 134450. | 80125. | 80125. | 54325. | 0. | 250000. | 250000. | 0. |
| 121. | 165988. | 80942. | 80942. | 85046. | 0. | 248158. | 248158. | 0. |
| 124. | 87450. | 80000. | 99480. | 7450. | -19480. | 80000. | 99480. | 19480. |
| 201. | 3265. | 3265. | 3347. | 0. | -82. | 3265. | 3347. | 82. |
| 214. | 5447. | 0. | 0. | 5447. | 0. | 6000. | 6000. | 0. |
| 216. | 784. | 458. | 458. | 326. | 0. | 840. | 840. | 0. |
| 225. | 987. | 715. | 882. | 272. | -167. | 800. | 987. | 187. |
| 265. | 1125. | 919. | 1002. | 207. | -84. | 1100. | 1200. | 100. |
| 301. | 3265. | 2762. | 2578. | 503. | 184. | 4500. | 4200. | -300. |
| 3240. | 154. | 0. | 0. | 154. | 0. | 200. | 175. | -25. |
| 3580. | 3479. | 3127. | 4581. | 352. | -1454. | 3500. | 5128. | 1628. |
| TOTALS | 432571. | 264466. | 285549. | 168105. | -21083. | 627608. | 648760. | 21152. |

MANAGEMENT RESERVE 125478.

## FIGURE 3.4.3:
## Sample MAT-PAC/WORK-PAC Labor & Material Summary Status Report

COMBINED MAT-PAC/WORK-PAC STATUS REPORT

WEEK 12 TUE 17MAR81 PAGE 1

PROJECT 1002. SPAR TEST SHIP II

| | TARGETS | | CURRENT STATUS | | | ESTIMATE AT COMPLETION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | LABOR MANHRS | MATERIAL $ US | SPENT LABOR MANHRS | % PROG | COMMIT. MATERIAL $ US | TOTAL LABOR MANHRS | MANHR SAVINGS | TOTAL MATERIAL $ US | MATERIAL SAVINGS |
| GROUP 0. STEELWORK | 474534. | 409530. | 474119. | 95. | 112000. | 499147. | -24613. | 409530. | 0. |
| GROUP 1. ACCOMODATIONS OUTFIT | 55112. | 66775. | 16832. | 28. | 11341. | 59170. | -4055. | 79116. | -11341. |
| GROUP 2. CARGO SYSTEMS OUTFIT | 56325. | 0. | 28273. | 63. | 37640. | 45235. | 11090. | 37640. | -37640. |
| GROUP 3. MECHANICAL SYSTEMS OUTFIT | 82615. | 0. | 48525. | 48. | 0. | 100815. | -18200. | 0. | 0. |
| GROUP 4 PIPING SYSTEMS | 82362. | 0. | 49454. | 61. | 0. | 74380. | 7982. | 0. | 0. |
| GROUP 5. MACHINERY SYSTEMS | 27866. | 0. | 14040. | 50. | 0. | 28210. | -344. | 0. | 0. |
| GROUP 6. ELECTRICAL SYSTEMS | 57978. | 0. | 16884. | 30. | 0. | 55486. | 2292. | 0. | 0 |
| GROUP 7 PRODUCTION SERVICES | 128516. | 0. | 85051. | 62. | 0. | 137174. | -8455. | 0. | 0. |
| GROUP 8 OWNER CHANGES | 7147. | 0. | 4508. | 58. | 0. | 7737. | -590. | 0 | 0 |
| GROUP 9 DESIGN & DRAWING | 27587. | 0. | 23059. | 81. | 0 | 28508. | -921. | 0. | 0 |
| PROJECT 1002. SPAR TEST SHIP II | 1000039. | 476305. | 760702. | 73. | 160981. | 1036062. | -36023. | 525286 | -41961 |
| MANAGEMENT RESERVE | 55000. | 75000. | | | | | 55000. | | 75000 |
| TOTALS | 1055039. | 551305. | | | | 1036062. | 18977. | 525286. | 26019 |

## 4.0 CONCLUSIONS

Correct project Cost/Schedule management requires a continuous review of production performance and the ability to act quickly to avoid or minimize problems. Correct planning, however, can relieve management of much on-the-spot problem solving, which oftentimes cannot be as successful once the project is under way. Planning identifies problems before they can occur and provides early opportunities to develop strategies that can avoid problems altogether.

The planning phase must concentrate upon not only the proper sequencing of work and establishing performance measurement goals (budgets and schedules), but also must further evaluate relative degrees of cost and schedule risk among project alternatives. Risk, in this sense, *refers to* the likelihood of over-run (time, money, or both) in completing the project.

A "Risk Review" process assesses the relative "softness" versus precision in project definition. Ill-defined (soft) requirements are more highly vulnerable to change and are therefore of higher risk. The risk review, then, determines those areas of the project of highest risk and initiates steps necessary to develop better cost/schedule definition. Factors that affect risk are the following:

a) Project size

b) Project complexity

c) Level of technology required

Added to these are certain organization-related risk factors:

a) Working skills and competance

b) Management skills and competance

Measures typically taken to reduce risk are the following:

a) Break down the job into smaller, more measureable phases

b) Reduce scope of work

c) Employ more standard methods

d) Implement smoother work procedures

e) Implement better performance measurement procedures

f) Seek alternate responsibility assignments

# APPENDIX I

## GLOSSARY OF TERMS

This section is incorporated to define the terms used throughout the documentation. The following is a list of those terms and their definitions:

**Account** — The WBS cost category to which an activity belongs. In addition, it will normally be part of the activity's work package number which is a necessary key in identification of the activity within the network.

**Activity** — An identifiable task in the total project having a start and finish date and sequenced relative to other project activities by the structure of the schedule network.

**CPM** — Critical Path Method, a procedure for determining activity schedules based upon their individual durations and lead times and upon the organization of activity sequences within the network.

**Delivery (D)** — The vessel will have reached the final completion of contracted work, and will be ready to be turned over to her owner.

| | |
|---|---|
| Dry Survey (DS) | This is the stage in production where all major steel work within a particular zone has been completed. The zone will now be ready for the start of on-board outfitting. |
| Dummy Link | A restraining connection between two activities. A dummy has zero duration, but may be assigned a positive or negative (overlapping) lead time between the two activities. |
| Duration | This is the time planned to accomplish the task. |
| Early Finish | Earliest possible finish date for an activity. |
| Early Start | Earliest possible start date for an activity. |
| Event | Specific point in time within the project network when activities begin and/or finish events correspond to network nodes. |
| Float | Same as slack time. |
| "I" node number | This schedule network event defines the starting point of an activity. Its identification number can be pre-determined, or be a variable of a zone or unit. |
| Item Number | A discrete number which uniquely identifies an activity within a given PERT-PAC Micronet. The chosen numbers should be sequential within the Micronet. |
| "I" node number | This schedule network event defines the ending point of an activity. Its identification number can also be pre-determined, or be a variable of the zone or unit. |
| Late Finish | Latest possible finish date for an activity after all slack time has been used; any further slippage in finishing the activity will slip the overall project completion date. |
| Lead Time | The extra amount of time expected to be required after a preceding activity, or set of activities, has been completed before a succeeding activity can begin. A negative lead time represents a succeeding activity that can start before a preceding activity has been completed. |

| | |
|---|---|
| Micronet | A small portion of the vessel's network which usually is incorporated into the network repeatedly. The Micronet Library, which is a part of the PERT-PAC scheduling system, is used to maintain all the vessel's Micronets. |
| Module | The placement of equipment and its related systems together on a machine foundation (seat) prior to its installation on-unit or on-board. |
| Node | A network event representing a point in time when activities begin and/or finish. |
| On-board Outfit | Installation of fittings, without prior assembly, on-board the vessel. This method of outfitting is normally the most expensive in terms of worker convenience, access to work, access to tools and materials, and overhead for crews' transfers to and from job. |
| On-unit P/O | A method of pre-outfitting which allows equipment to be assembled and installed as a unit, in the shop, independently of the vessel structure. This procedure normally enhances safety and reduces manhours and work durations over other methods of outfitting, such as on-board outfitting. On-unit pre-outfitting may also refer to all the assembly of outfit modules. |
| Panels | Sub-divisions of units being processed through the assembly shop. |
| PERT | Program Evaluation and Review Technique that utilizes CPM procedures for computing activity schedules. PERT also calculates odds on any given date actually happening using a very simple statistical computation upon three (3) separate manually derived estimates of duration for each network activity: most likely, most optimistic and most pessimistic. PERT-PAC, contrary to its name, does not perform this probable odds analysis. |
| Pre-outfitting | Outfitting on steel assemblies as opposed to on-board the vessel. |

| | |
|---|---|
| Slack Time | The scheduled leeway which allows flexibility in the duration of an activity without adversely affecting the schedule of any other activity, or the completion date for the overall project. |
| Sub-assembly | A definable unit of product to be delivered. |
| Sub-net | An isolated collection of activities within an overall larger network. |
| Units | Hull structural assemblies composed of several panels and being erected as a whole on the ways. |
| Variable | When the "I" and "J" node numbers are not fully defined, they will be a variable of the zone or unit. Their numbers will be automatically generated by the system, based on the input data. |
| WBS | Work Breakdown Structure or chart of acounts, usually representing each engineered ship system and hull structure, plus ship construction support and management services. |
| Work Centre | An area of the yard or ship where an activity (work package) is to be performed. It is a necessary key in the identification of an activity within the network. |
| Work Package | A distinct and definable unit of work that can be started and completed without significant interruption under the direction of a single work centre. |
| Zone | An optional breakdown of a project's product definition useful for added cost/schedule control purposes. |
| Zone Complete (ZC) | This is the stage in production where all steel work, pre-outfit work, and on-board outfit work has been completed. |
| Zone Ready (ZR) | This event indicates that the zone is ready for the start of on-board outfitting. |

# THE CONCEPTION AND CONSTRUCTION OF A HIGH PRODUCTIVITY BARGE BUILDING SHIPYARD

Frank H. Rack
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Mr. Rack has more than 20 years of shipbuilding management and consulting experience. At Todd Shipyards Corporation, Galveston Division, he was one of a four-man team responsible for design of a new $100 million shipyard to build ULCC including all new facilities, organization and operation. At General Dynamics Corporation, Quincy Shipbuilding Division, he directed all aspects of the operations departments in support of the LNG and VLCC programs. Prior to this he was responsible for the 180-acre facility, all maintenance, production engineering, ship services and research laboratories. He also participated as member of SNAME Panel SP-2 Production Methods.

Mr. Rack holds a BS degree from the United States Merchant Marine Academy.

## ABSTRACT

Shipbuilding Consultants, Inc. (SCI) of Dickinson, Texas acting as consultant to Bergeron Industries, Inc. (BII) of St. Bernard, Louisiana and with the assistance of the Carlson Corporation (CC) as architect/engineers, conceived, designed and constructed a new high productivity shipyard on a 88 acre site near Demopolis, Alabama for rapid multiple construction of barges up to 300 foot length size range. One barge is to be delivered every other day. Five major modules per barge are fabricated and assembled by an indoor semi-automated production line feeding sequential outdoor erection positions. Barges are launched via a winch controlled launch system from the elevated site which is 80 feet above the Tombigbee River. This paper describes the facility layout and production features. Further the actual construction from ground breaking (9/28/81) to first barge christening, and facility dedication (4/21/82) to first barge launch (6/29/82) in nine months is discussed.

In early June 1981 Bergeron Industries, Inc. (BII) retained Shipbuiling Consultants, Inc. (SCI) to develop a production plan for the efficient construction of "super jumbo" open hopper barges measuring 260 feet long, 52.5 feet wide and 12 feet high with a 4 feet high coaming. One barge is comprised of 580 tons, and has double the capacity of the conventional inland waterways hopper barges.

The production plan included the design and construction schedule for a new facility since BII's existing plants in Lousiana and Mississippi had contract backlogs which precluded meeting additional demands.

In July 1981 BII incorporated a new subsidiary, Bergeron Barges, Inc. (BBI). BII's foresight and determination resulted in the award of a $60 million contract to BBI believed to be the largest single inland hopper barge contract ever awarded to one company. The contract was awarded to BBI by Central Gulf Lines, Inc. to construct and deliver 116 super jumbo barges by early 1983.

This contract led to the development of BBI's Demopolis Alabama plant, an 88 acre site located on the Tombigbee River. In building the $10 million modern facility over three quarters of a million cubic yards of dirt were moved, one and a half miles of railroad track were laid and a 100,000 square feet building was constructed to cover the highly automated fabrication and assembly equipment and work areas.

SC1 acting as BBI's "Turnkey Manager" contracted to the Carlson Corporation (CC) for preliminary civil engineering and construction estimates. The final site was selected after surveys and soil evaluation were completed. CC was retained for engineering and construction management.

Figure 1 indicates the actual schedule that was attained leading to a successful barge launch nine months after groundbreaking. One of the more interestings items of the many involved during construction was the establishing of an earth dam which permitted the completition of all four launchways prior to the dam removal in May 1982.

The slides and photographs indicate the construction progress.

Figure 2 is the layout of the shipyard and also indicates the outside work stations.

## Production Plan

The production plan was designed for maximum efficiency at each operation. Adequate capacity was planned to provide for the required throughput of two and one half barges per week. This rate has yet to be attained for various reasons which will be discussed as each work station is reviewed.

Figure 3 lists each work station along with a brief description of the work performed at that station.

Figure 4 is a layout of the fabrication and assembly building and also indicates all work station locations. The slides and photos indicate more of the details of each work station.

The heart of the production plan is a collection of equipment conceived by SC1 and built and installed by Ogden Engineering Corporation (OEC) which results in the fabrication of stiffened panels utilizing efficient methods. These stiffened panels represent the majority of the fitting and welding in the barge. These stiffened panels are then combined into erection modules which in turn are welded by semi-automatic equipment prior to erection.

Figure 5 is a layout of the panel line and Figure 6 is a summary of the feet of welding and the number of stiffeners fabricated for one barge on this panel line.

The following additional items contribute to the productivity of the operation:

- All material entering the fabrication and assembly building exit as a completed module. Only five modules are required to build a complete barge.

- 0 Jigs and fixtures are utilized for most subassemblies and assemblies.

- 0 Only two modules are erected by the crane. Two modules are erected by hydraulic lifting arms and one is "transferred" into its erection position.

- 0 Efficient module and barge transfer system.

- 0 Nine building positions are available if required.

- 0 Sufficient height under the barge in the blast and paint area (station 32) for men to work under barge.

In addition to BBI's Demopolis facility, SC1 has been deeply involved in actual modernization of facilities at General Dynamics, Quincy and Electric Boat, Bay Shipbuilding, Port Allen Marine, Nashville Bridge, St. Louis Ship (Caruthersville), and Bergeron Shipyard *over* the last twelve years. The most important lesson learned from these experiences is that the degree of success is completely dependent on "people".

Good white and blue collar workers are required to attain the cost savings and to meet the schedules estimated at conception.

The second important lesson learned is that a good Management Information System (MIS) is required. The heart of the MIS is a good Planning and Production Control (PPC) system. Most knowledgable shipbuilders do not require MIS or PPC if they get the plans and material on time, however Management needs the systems in order to "MANAGE".

FACILITY SCHEDULE

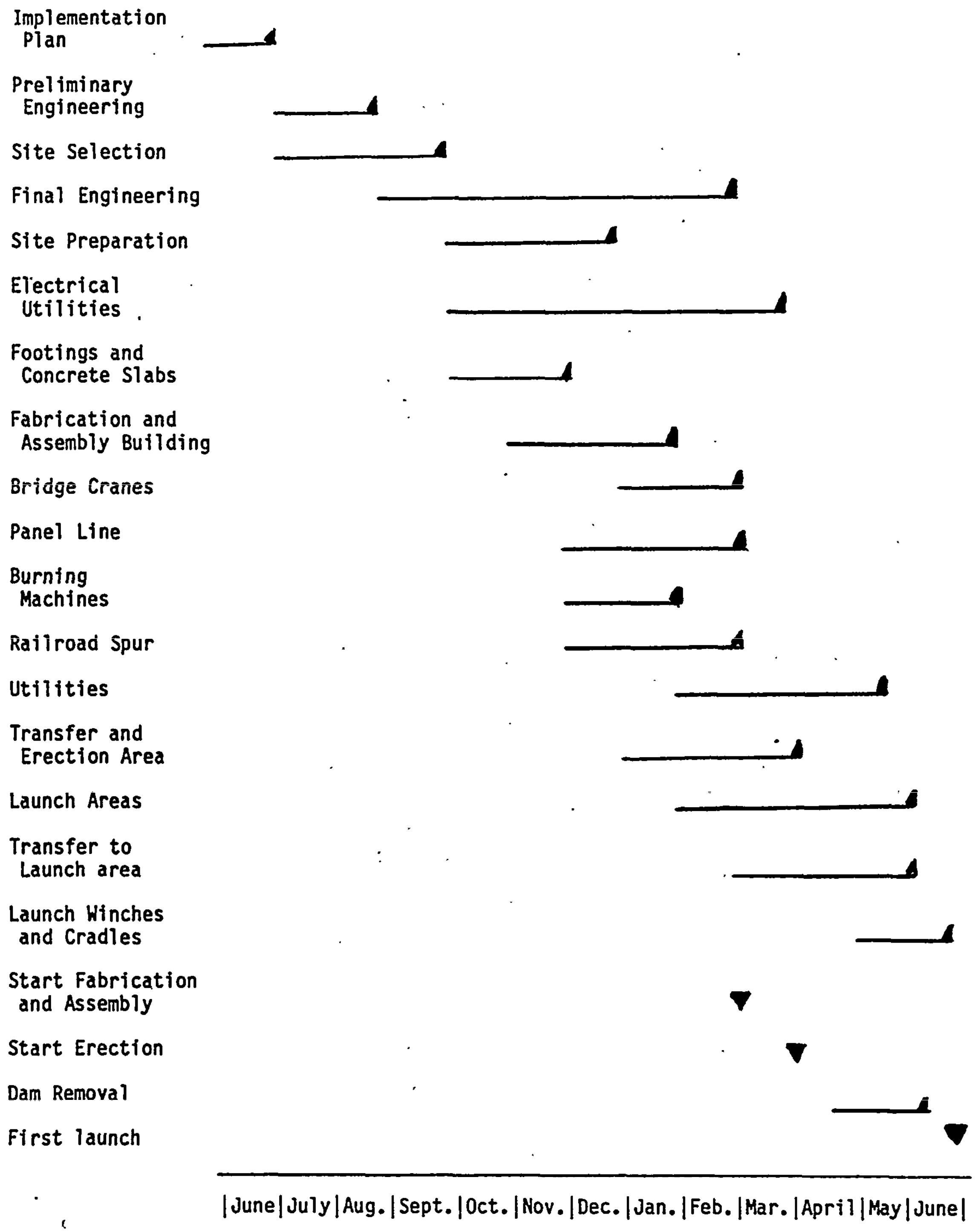


Figure 1

# SHIPYARD LAYOUT

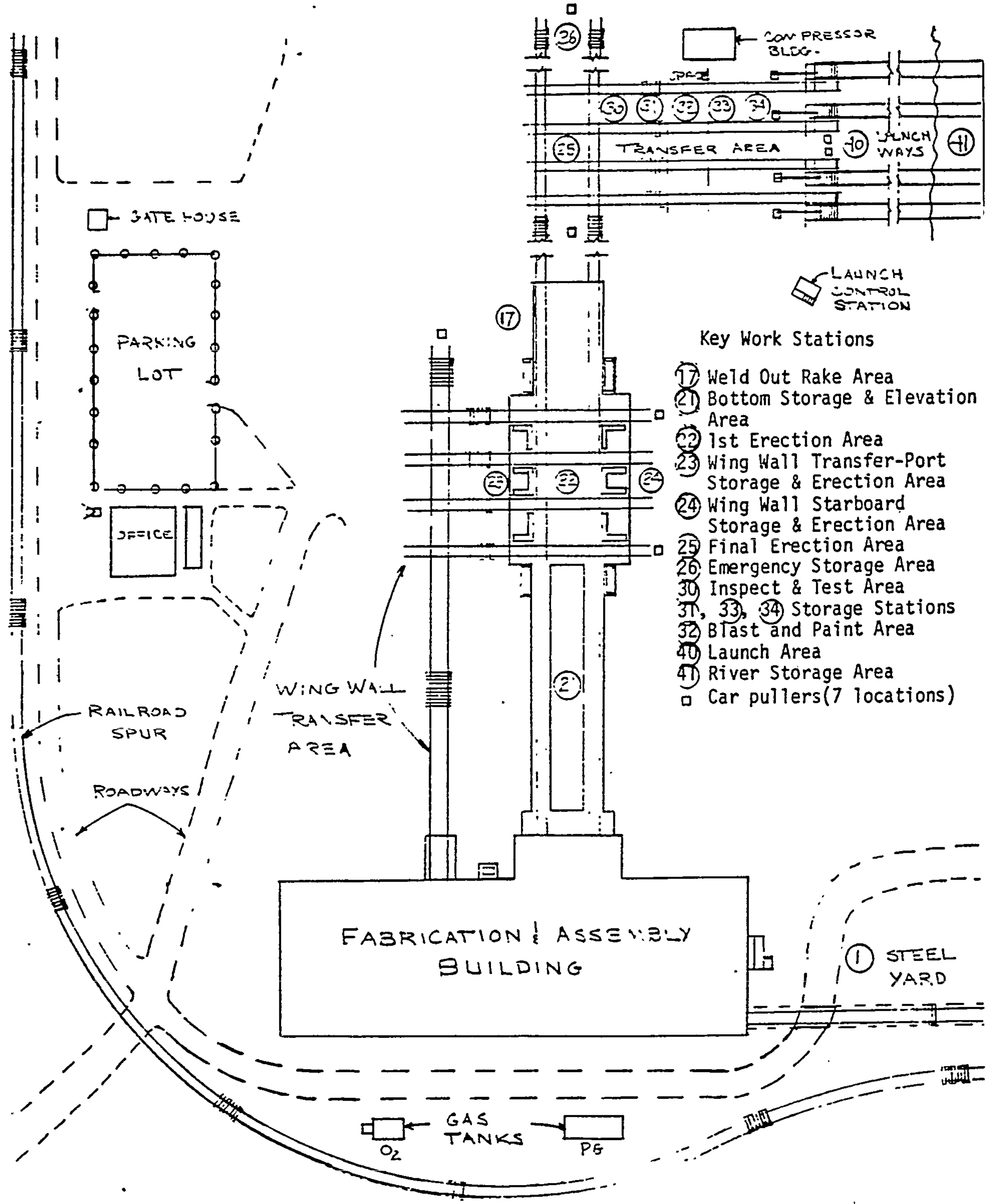


Figure 2

## Work Stations

| No. | Title | Description |
|---|---|---|
| 1. | Steel Yard | Storage area for raw steel plate, shapes, and barge material. |
| 2. | Flame Plane | Burns raw plate into square rectangular plates. |
| | DNC Burn | Burns contour parts and also squares plates. |
| 3. | Shear | Mechanically shears plate. |
| | Press Brake | Bends plate and,shapes using dies and templates. |
| 4. | Bergeron Bender | Bends plate to radius of forming cylinder. |
| 7. | Inlet Buttweld | One sided butt welds up through 5/8" using magnet bed for alignment. |
| 8. | Panel Stiffener | Automatically fits and welds up to nine stiffeners per panel. |
| 9. | Exit Butt Weld | One sided butt welds stiffened bottom panels to each other using magnet bed for alignment. |
| 10. | Tank Top Fitting Area | Fits Tank top plates and plug weld to bottom panel floors. |
| 11. | Seam Welder | Seam welds tank top plates to bottom floors and to each other. |
| 12. | Iron Worker/Angle Roll | Iron worker cuts various shapes. Angle Roll rolls Angles. |
| | Wing Wall Unit Assembly Area | Assembly of sub assemblies into wing wall units. |
| 14. | Wing Wall Module Assembly Area | Assembly of Wing Wall Units into complete module. |
| 15. | Stern Assembly Area | Assembly of complete stern section utilizing various jigs. |
| 16. | Rake Assembly Area | Assembly of campleted rake section. Assembly jigs used to make rake sub-assemblies. |
| 17. | Weld Out Stern/Rake Area | Complete internal welding and attachments to Rake and stern. |
| 21. | Bottom Storage and Elevation Area | Completed bottom storage area, barge is lifted up and buggies transfer to station number 22. |
| 22. | Wing Wall and Rake Erection Area | Wing walls and rake are erected to bottom. |
| 23. | Wing Wall Transfer, Port Storage and erection Area. | Transfer of wing walls out of shop. Port Wing Wall storage and erection. |
| 24. | Wing Wall Starboard Storage and erection Area. | Starboard wing wall storage and erection. |
| 25. | Stern Erection and Structural Completion | Stern erection and final structural work. |
| | Emergency Barge Storage Area | Storage Area for emergencies. |
| 26. | Final Inspection and Test Area | Pick up, inspection, and test. |
| | Barge Storage Area | Barge Storage if necessary. |
| 32. | Barge Blast and Paint Area | Exterior Blast and Paint Area. |
| | Barge Storage Area | Blast and Paint block areas-Barge Storage. |
| 34. | Barge Storage Area | Barge Storage if necessary. |
| 40. | Launch Area | Controlled launch of barges using winches and cradles also Haul out of Barges. |
| 41. | River Storage | River Storage and fleeting of Barges. |

Figure 3

# FABRICATION & ASSEMBLY BUILDING

Key Work Stations

1 Steel Yard
2 Flame Plane
3 DNC Burn
4 Shear
5 Press Brake
6 Bergeron Bender
7 Inlet Buttweld
8 Panel Stiffener
9 Exit Butt Weld
10 Tank Top Fitting Area
11 Seam Welder
12 Iron Worker/Angle Roll
13 Wing Wall Unit Assembly Area
14 Wing Wall Module Assembly Area
15 Stern Assembly Area
16 Rake Assembly Area
* Future Installation

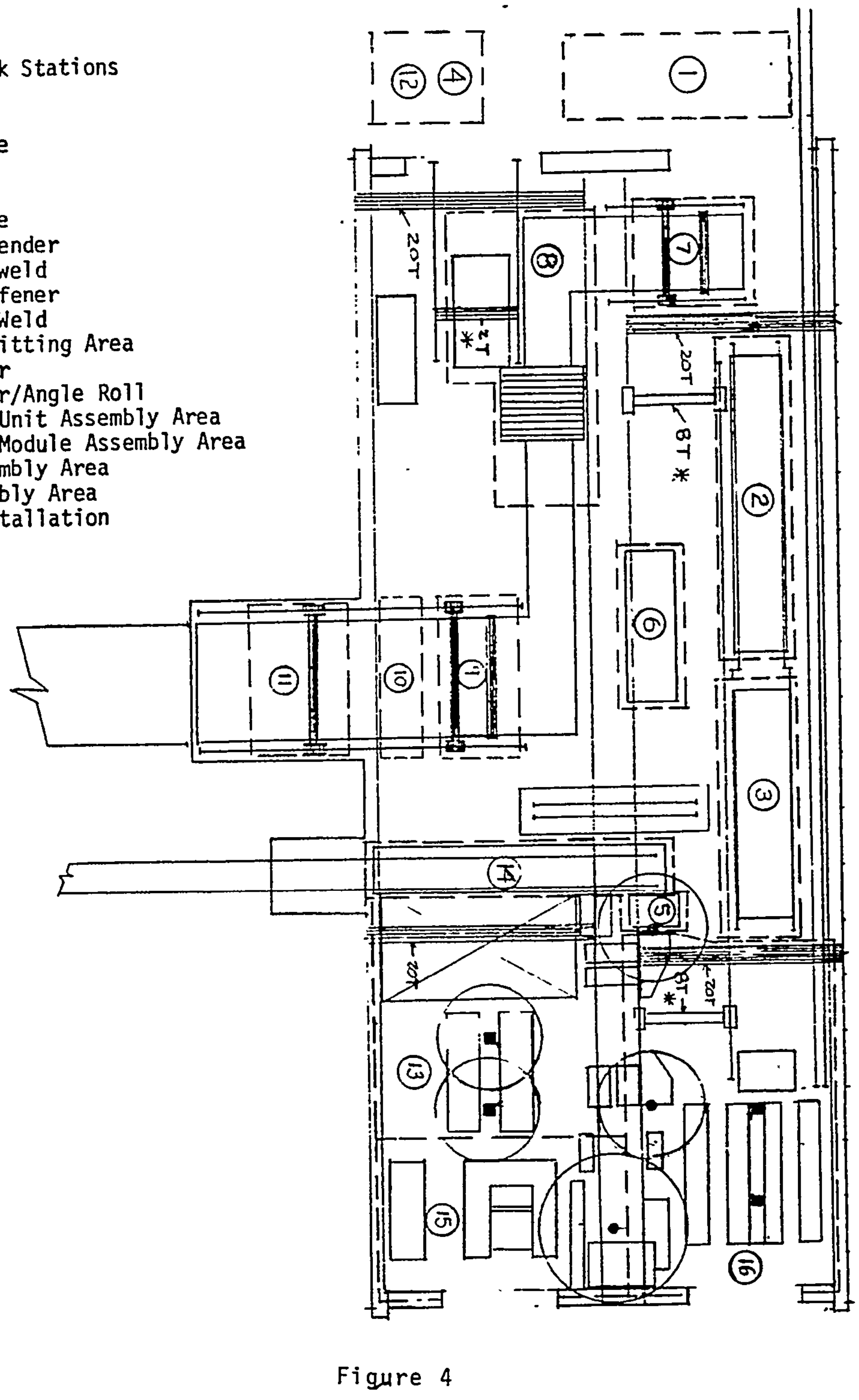


Figure 4

# OGDEN PANEL LINE

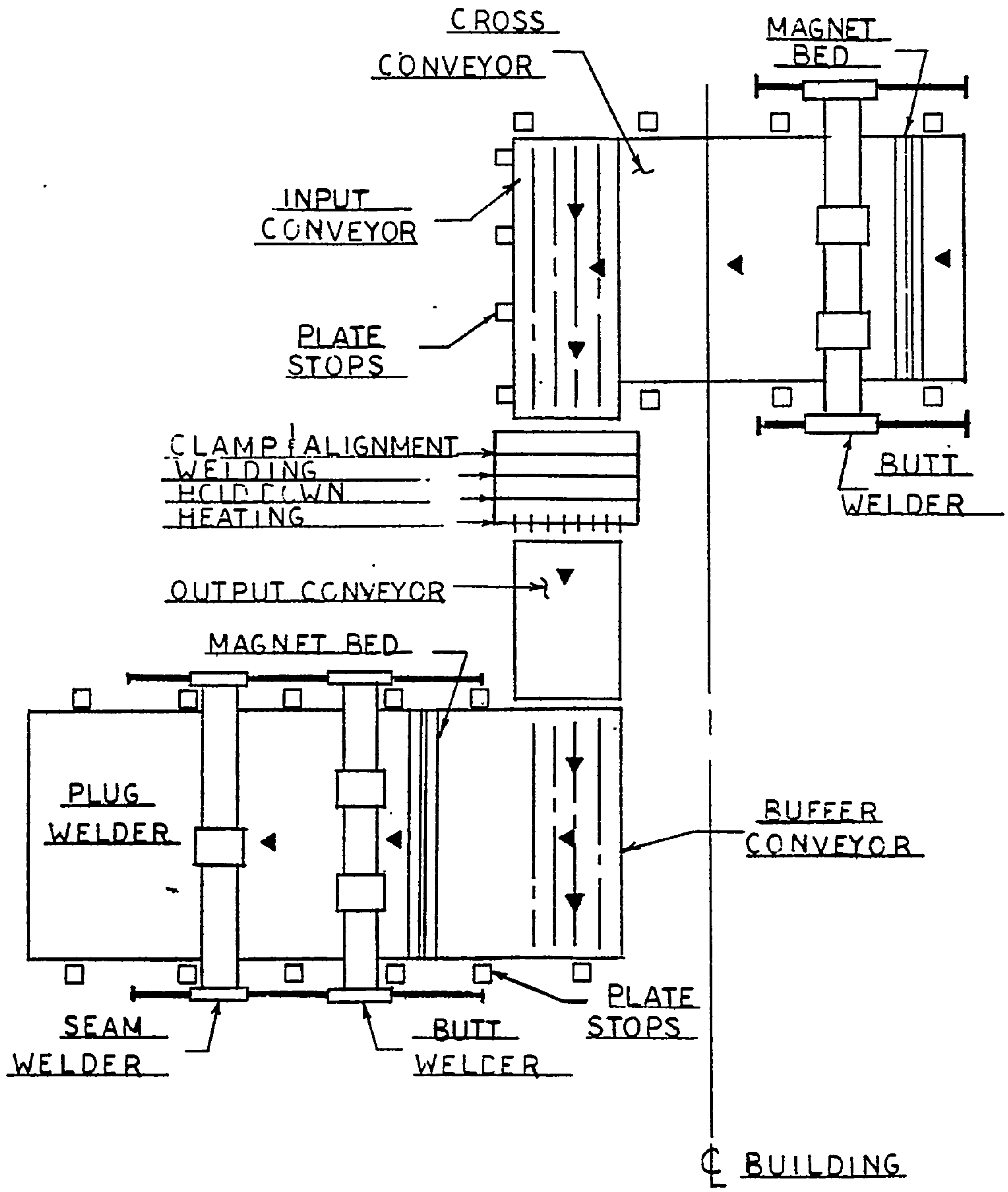


Figure 5

## PANEL LINE PER BARGE SUMMARY

| | Inlet Butt Weld | | Panel Stiffener | | | Exit Butt Weld | |
|---|---|---|---|---|---|---|---|
| | No. of Welds | Total Ft. of Welds | No. of Cycles | Total No. of Stiffeners | Total ft. of Weld | No. of Welds | Total ft. of Welds |
| Bottom 50' | 24 | 1200 | 12 | 107 | 10700 | 11 | 550 |
| Side 50' | - | - | 9 | 54 | 5400 | - | - |
| Hopper 50' | 9 | 450 | 9 | 36 | 3600 | - | - |
| Side Deck 50' | tack | - | 3 | 9 | 900 | - | - |
| Rake Bottom 31' | 6 | 186 | - | - | - | - | - |
| Rake Deck 27' | 2 | 54 | 3 | 18 | 972 | 5 | 135 |
| Rake Bulkhead 50' | 1 | 50 | - | - | - | - | - |
| Transom Plate 50' | tack | - | 1/3 | 3 | 300 | - | - |
| Stern Bulkhead 50' | - | - | - | - | - | 1 | 50 |
| TOTALS | 42 | 1940' | 36 1/3 | 227 | 21,872' | 17 | 735' |

Figure 6

NSRP #0009
Paper 7

# SO YOU WANT TO USE ENGINEERING MODELS

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Mr. Rohrer is currently responsible for all phases of model operation and marketing. He has over 20 years experience in management, management systems, and marketing. Associated with the engineering model industry for over 10 years, he has been instrumental in promoting the engineering model concept in the United States.

Mr. Rohrer is a graduate of Williamson Trade School, holds a degree in engineering, and is working toward a degree in administration.

## ABSTRACT

Concerns and requirements for making use of models within your company are presented. Alternatives are weighed, suggested approaches are provided, and some of the people requirements, and other resources necessary to have a successful program are discussed.

A new model program must be planned into the design program--it must be sold to management and the various design personnel, and integrated into the present way of doing things. How effectively you do this can mean the success or failure of your model program.

## INTRODUCTION

I don't like to start by introducing a note of caution, but any tool, including engineering models, is only as good as the understanding and skill with which it is used. If it's properly used, you are going to get better engineering design, more effective communication and cooperation among engineers and shipbuilders, in addition to being a useful aid to management in reviewing design and monitoring and guiding design progress.

Now, I am going to try to give you some practical guidelines for deciding what kind of model program you need, how you sell management on a model program, and how to plan and integrate it into your organization. Whether you are considering a model program for the first time or are simply dissatisfied with the results of your current one, the outline of initial considerations in developing a program and the steps in planning, staffing, implementing, and supervising the program should be helpful.

The first question many people ask is "how much does a model program cost?" This is difficult to answer in exact terms of dollars and cents. Programs vary. The important thing to remember is that costs must be weighed against sizable savings achieved through the elimination of up to 60 percent of drawings, shortened schedules, and reduction of construction rework and delays. The more appropriate question, in fact, is "How much does a model save?" The answer to that is that it can be up to fifteen percent of total project costs. So, it is quite safe to say, that in the end, an effective model program will cost you nothing.

You will note that I said effective model program. A model program must be carefully planned and supervised. There must be strict adherance to schedules and budgets and management must be knowledgeable about and supportive of the program.

## INITIAL CONSIDERATIONS

The first thing to do is to define your needs and objectives - that is, to ask yourself what it is you hope to achieve through the use of models.

Is cost savings the primary objective. Or is it improved communication among groups responsible for various aspects of the design, or perhaps,'reduction

of project time. How extensive is your requirement for models for design and/or design check purposes?

Depending upon what objectives you have in mind and the resources available to you, you may choose one of the following alternative approaches:

(1) A "captive" or total in-house model program. (2) A "subcontract" or in-house program with supplemental services of an outside model services company, or (3) A program utilizing models built entirely by an outside model company, usually in their own model shop.

A captive program has the advantage of being totally under your own control and more convenient to manage. Model technicians are your own employees who are responsible permanently and solely to you. On the other hand maintaining a full in-house program over the long term can be expensive especially for smaller design companies or design companies where the model workload is light or fluctuating. One way to overcome this problem is to use short-term contract modelers or "job shoppers". These temporary employees, who are hired to work for a specific period of time, usually three to nine months, are generally competent in the complete range of modeling activities, but most often assist with the design and installation of piping systems. These trained modelers are more costly, but in a pinch, they can help you get the job done quickly. They are available from a number of sources, but preferably they should be associated with a company whose primary business is engineering modeling.

One variation on the captive approach is to develop your own in-house program, but have outside model consultants staff it as needed. This is useful for companies who have been unable to make use of models because of lack of people, facilities, know-how, or a sustained requirement. For companies already using models, it can afford an overhead free program, except for space and utilities.

If you use the "subcontract" approach, you can save on investing in a model machine shop by having the basic model built by a reputable model service company and do only the piping and other distributive systems design in house. This approach is gaining in popularity especially among companies just getting established in modeling and companies that do not have a continuous model required workload. There are several model service companies that can help you get your model program under way.

Finally, you may decide to have an outside model service company produce a model for you in their own shop. Such models are often called "check models', and are used by companies to evaluate their design decision and drafting systems. Many times a "check model" is a company's first introduction to modeling. Not many "check models" are built because it usually adds cost to design.

Another important consideration at the outset is how the model will tie in with other methods of developing, communication, and evaluating design concepts. As you are probably well aware, there are three such methods: conventional engineering drawings, models, and computer aided design.

Each has certain advantages and disadvantages. When they are used in combination, the results far exceed those for any of the techniques used alone. Models and computers, for instance, are not competitive, but complementary. Models are excellent inputing devices for computers. At the same time, computers can quickly check design information and perform calculations necessary for construction and for pipe fabrication and installation.

The future indicates an ever-increasing role for the computer in design and engineering, but it also establishes the three-dimensional model as an ideal medium for developing and coordinating input for the computer.

Once you have decided which type of model program is best for you and how the model will be used in relation to other design methods, you can begin shaping your model concepts for management approval.

## SELLING MANAGEMENT

Assuming you need a model program in-house, the first job is to sell management all management - on the value of the program. To do that, you will need back up information. When you've captured management's interest with rapturous stories of interferences found, dollars saved, and schedules met, by the competition through use of models, you have to be ready with a battle plan to press your advantage, which initially means attacking the problem of planning a successful model program.

So, first you find out how the most successful have planned their model programs and develop your own plan on the basis of your needs and the good ideas you've obtained from everyone else. Seminars, publications, visits to companies using models will all help you see the various ways in which others have developed successful programs - or, just as important, show you what mistake to avoid.

The first thing management is going to want to know is "how much?" As we said earlier, the answer is "nothing", but the accounting department probably won't accept that answer readily. That means you're going to have to come up with the following: space costs, machine and tool costs, materials costs, and personnel costs. Depending upon the size of your shop the number and kinds of projects you anticipate undertaking during the first two years - the costs will vary considerably.

The next step is to put the dollars in your estimate against the actual cost of design procedures currently being used and the cost of schedule delays and cost overruns on recent projects that can be attributed to inadequate design review procedures or schedule problems.

This comparison should yield not only a favorable cost factor, but by implication, greater confidence in the design quality obtainable through use of models.

By now, you should have a list of objectives, and budget requirements, a specific location, and a cost analysis of setting up the model shop.

Now you're ready to present all these to management. If you have established the need and your cost analysis supports your argument, you should have little trouble making your case. Once management has approved your plan, you have to retain their support by keeping them informed of progress and making the models convenient for management to use.

You should view yourself as a General embarked upon directing a successful campaign, the goal of which is to prove the value of your recommendation and accomplish the objectives you have already defined. If the campaign is successful you should not be surprised when management takes the credit. After all, every General knows that if the Commander-in-Chief takes the credit, the campaign was a success. Management might never know the reasons for the increased quality, or improved cost effectiveness, or other benefits

that come out of the model program, but the successful implementation of a model program will speak for itself and in all likelihood justify continuation and expansion of the program.

## FITTING THE MODEL PROGRAM INTO YOUR EXISTING FRAMEWORK

Management's blessing is essential, but they are not the only ones who have to accommodate to a new system. The program must be properly integrated into current operating methods in order to work. Changes and adjustments have to be made. Remember the model is taking the place of other procedures.

Probably the most critical consideration is the placement of the model section in the organization. Its placement will define the way in which engineers will use the model and the frequency with which it will be used. Indirectly, these factors will affect the ultimate success of the model program.

Placing the model section under a particular project is a frequent, but puzzling mistake made by many people. The model section must be regarded as a design resource for all projects rather than an anomaly associated with only one project. Generals, and marketing managers know that, next to timing, position is everything - so position the section organizationally and physically for maximum use and visibility. It is a load bearing key activity in the structure and has to be centrally placed.

Another crucial task will be to educate management, engineers, and designers to use models. The initial introduction to the value of an in-house model program should probably be accomplished through a seminar conducted by a consultant from a model engineering firm. Everyone claims to suspect the briefcase-carrying consultant, but nevertheless we tend to listen more readily to the outside expert than to the in-house one. The formal seminar should be followed by guided tours of new section, an explanation of its capabilities and an introduction to the equipment and people who will be providing the modeling services to the engineers.

One major purpose of internal training sessions is to get designers and draftspersons to think "3-D". A surprising number of people still think the world is "flat", that is, that design concepts can be developed only

on conventional two-dimensional engineering drawings. Even though these people may not understand their drawings totally, they are like a crutch. Models eliminate a large proportion of drawings. It's mostly a matter of convincing people they can toss away the crutch and perform better without it.

Integrating the model program also involves developing communications channels among the various design disciplines, modelers, construction supervisors, and management. Models are communications tools as well as design tools, and in that respect, greatly enhance the design process. Unless communication is made easy and encouraged, it won't happen, and the value of the model will be diminished.

## STAFFING

With the smoothest possible transition as your goal, the first step in actually implementing the model program is the selection of a model supervisor. He is the most important person in the model program. Get a pro. This is the man who is going to decide what equipment and materials you need, assess the number of man-hours needed for a job, establish communications with the engineers, and a hundred other things that all add up to proving you were right to push for your own model program.

The model supervisor, usually a permanent employee hired by the Manager of Engineering, should be a results-oriented professional with a background in engineering and several years' supervisory as well as modeling experience. He must be able to lead and make decisions.

This person who is going to provide administrative, technical and political direction for your model shop has to be able to develop standards and procedures your engineers can understand. He has to understand the importance of modeling for specifications rather than "detail-for-detail's" sake - a hazard, by the way of looking at hobbyists as prospective engineering model technicians. He has to know how to set up the necessary controls and procedures to assure that the model is kept up-to-date. He must be a good communicator, and his communication ability must be both verbal and written.

The model supervisor will provide a valuable service in helping the technicians. The model technician should be experienced model builders, or offer the qualifications of a model technician trainee. At least eight credit hours in addition to basic math, algebra, and geometry. Of course, previous experience in the engineering modeling or related fields is always desirable.

You might even consider women. They have a couple of advantages, smaller hands to fit in small places and usually superior fine motor skills. Regardless of whether you hire a male or female, hire someone who is qualified. Do not let the hobbyist learn engineering modeling on your time and money.

## PLANNING

With the model supervisor aboard, you can begin detailed planning of the program. There are several initial tasks you must begin working on:

- Design of space for shop
- Selection and ordering of equipment and supplies
- Establishing model construction procedures
- Establishing safety standards
- Establishing standard construction codes
- Establishing inventory procedures
- Developing model specification forms
- Developing a model project control system

This series of tasks, implemented at the beginning of the program, will ensure a quality model program that will serve well the goals of engineers and management.

Many of these details are outlined in "Model Handbook", available through the American Engineering Model Society.

The physical location of the model section is extremely important. It should never be very far from the center of design activity. If you have a machine shop, it should be located on the ground floor with street level access or in a separate building. Ground location of the machine shop

and paint spray booth is generally preferable from the standpoint of fire regulations compliance. Double doors make it easier to move models and material in and out of the machine shop.

Model construction procedures, governing designers and draftsmen as well as modeling technicians, should be written out in detail and include a section on safety, that covers housekeeping, machine usage, small hand tool usage, and first aid. These procedures should be signed off first by the model supervisor then his immediate supervisor, and finally the head of the department.

Model construction standards covering such things as color coding, detail, scale, tolerance, and tagging must be developed. These standards help to maintain consistency from one project to the next and effect economies in model parts inventory and painting, which is expensive and undesirable.

Fill-in-the-blank Model specification forms also must be developed. A specification form lists all of the possible items that may be modeled.

On a particular project, the model supervisor should issue this form as soon as he knows the intended use of a proposed model. Once the model specifications are established and approved, any changes or additions must be accompanied by signed approval from the model supervisor.

Finally, you need a simple model project control system, consisting of time records and model progress log books with records of design changes and resolutions. It may well be an extension of your existing system.

The model must be an integral part of the scheduling for critical path milestones. If the model falls behind schedule or ceases to be effective, management, justifiably,, will question its value as a design tool. Ideally, the model section should be the place of formal and informal design reviews.

Now it is time to start building the model. The model program supervisor must direct his attention to directing the work of the model technicians and coordinating the flow of information. From this time on it is a continuous effort to build the model and encourage everyone involved to use the system properly.

After the model is complete a disposition must be made. The model will generally be shipped to the construction site. Here the model will be used primarily for planning the construction of the ship. If the model is required to be transported a long distance it is usually contracted to a model service company, or shipped in a dedicated moving van by a moving company.

Well, you can see that this whole process is very simple. I have in less than the space of half an hour told you how to plan, set up and integrate your model program into your existing organization. As in most other endeavors, the most important point is at the beginning: Know where you want to go, why you want to get there, and then draw up a battle plan. That is essentially what I have done. I have identified the objectives and then developed a simple management strategy for attaining them.

Control and integration of a model into an organization are critical to the successful use of a model. When a model, intended as a design tool, ceases to function as one, you have lost the battle. With careful attention to the steps we have outlined, however, we think you can launch a successful campaign and prove that models are indeed effective tools with which to ensure quality design and reduce design time and cost. The range of possibilities you have for using models is limited only by your imagination.

# MODERN SHIP REPAIR TECHNOLOGY APPLIED TO NAVAL VESSELS

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Mr. Shoemaker is presently in charge of implementation, of an automated planning and scheduling technique at Norfolk Naval Shipyard. This technique is based on outfit planning and product work breakdown structure methods developed under the National Shipbuilding Research Program.

Mr. Shoemaker has over twenty years shipbuilding experience in both new construction and repair. Major assignments have included new design work on CVN class reactor plants, and Q.A. engineering in a repair environment. He holds a Bachelor of Science degree in engineering technology from Old Dominion University.

## ABSTRACT

During the past several years the Maritime Administration has sponsored the National Shipbuilding Research Program (NSRP). The primary thrust of this program has been to identify those techniques which have enabled the Japanese to become world leaders in shipbuilding.

To date, the NSRP has been directed primarily toward new construction. However, in the Fall of 1981, Norfolk Naval Shipyard embarked on a program to adapt these techniques to the repair of naval ships. This effort is based on the Outfit Planning and Product Work Breakdown Structure methodology presented in the NSRP publications.

Further, a mini-computer system has been installed at Norfolk which allows schedules to be produced in a real-time manner. This system allows the shipyard to take full advantage of the NSRP techniques.

## 1. INTRODUCTION

The Naval industrial community has recognized that Naval shipyard productivity must be improved if we are to successfully meet the overhaul and repair needs of an expanded fleet. In-order to meet this challenge, Norfolk Naval Shipyard (NNSY) has focused on the proven shipyard techniques which have been developed under the Maritime Administration National Shipbuilding Research Program (NSRP). The NSRP publications, "Outfit Planning" and "Product Work Breakdown Structure", combined with a real time mini-computer system, form the basic framework for this effort.

To date, the primary thrust of the NSRP has been toward new construction; therefore, the challenge to NNSY is to adapt the new construction methodology to overhaul and repair work. Some Naval overhauls are larger in scope and manhours than many new construction contracts. Moreover, the complexity of overhaul work is increased due to the need to maintain portions of systems in an operable condition throughout the overhaul period.

## 2. BACKGROUND

### 2.1 Systems Orientation

Historically, all work in Naval Shipyards has been planned, scheduled, executed, and tested on a system by system basis. The system method has developed for several valid reasons which include:

- cost estimating
- cost accounting
- material estimating
- ship operation by system
- system test

Ship operators normally identify required work to a shipyard on a system basis. This method is acceptable and necessary to the shipyard for some categories. However, when the shipyard actually performs the repair work it is not done solely on a system by system basis. A close examination of any ship repair effort will show that work is planned, scheduled, executed and tested based on several criteria, one of which is the ship's functional systems. Other considerations must include:

- Geography, i.e., physical location of work
- Manpower required to perform work Availability of manpower
- Other work required to be performed in the same space
- Similar work to be performed in other areas of the ship
- Availability of material

All of these parameters are currently considered and resolved by shipyard management, usually the trade foreman or general foreman. These decisions are made on a trade by trade basis when the work is actually started. This method does not allow for an objective, analytical examination of the best possible way to perform the work. Neither does it provide a formal method of feedback, thereby increasing the corporate knowledge of the shipyard rather than the knowledge of the individual.

A further problem with the system by system approach is that the overall plan for completion of the overhaul is known, and fully understood only by a few individuals. Typically, these individuals are not the foremen and general foremen who are making the day to day waterfront decisions. For example, pipefitter and outside machinist foremen should not be expected to know all of the work to be performed in a given space. However, their decisions may directly impact upon the electrician's work. This often causes items to be installed in an improper sequence which results in unnecessary rework.

## 2.2 Zone Orientation

The work required for any large construction (or repair) project must be subdivided in order to be readily analyzed and managed. Any such subdivision scheme is a work breakdown structure.[1]

In order to subdivide repair work the "Zone Outfitting" and "Product Work Breakdown Structure" techniques published by the Maritime Administration have been closely examined. These techniques allow a repair yard to plan, schedule, execute and test production work in the manner in which it is actually performed i.e. across system and across trade boundaries. The work is broken into manageable blocks or zones which cross system and trade boundaries; and zone size may vary to suit the work at hand. A zone may be a single component or the entire ship. The zone concept of planning and scheduling allows the day to day decisions presently being made by waterfront foremen to be made at an earlier time in the overhaul, in a more objective manner. System by system planning is not eliminated by the zone technique. Indeed, sorting of work by system is in fact made easier and more meaningful when Zone Orientation is used.

## 2.3 Mini-Computer

As one explores the subdivision of a ship alteration/repair package beyond the traditional system by system approach, it becomes apparent that there is a significantly larger amount of information to be dealt with when using the PWBS technique. Unlike new construction, repair work must not only consider the production work and testing sequence, but must also consider those systems (or portion of systems) which must remain on-line throughout the overhaul.

In order to manage this large amount of information the need for a computer becomes readily apparent. Norfolk is attempting to use a relatively small mini-computer system for this effort. Our system is known as "PROMPT," an acronym for production oriented management planning technique, was developed by Science Applications, Inc., of La Jolla, California. The present hardware configuration includes a DEC PDP 11/44 processor with six CRT stations and a Printronix printer. PROMPT allows the sorting of detailed schedule information into various management reports. It futher provides a graphics capability which enables us to produce automated PERT schedules. We are presently using the PROMPT system to create working schedules at Norfolk.

# 3. PERTINENT TERMINOLOGY

3.1 Group Technology. Group technology applied to ship overhauls is the systematic grouping of similar repair processes to match common labor skills. Work is grouped by production process rather than by ship's systems.

3.2 Conventional Outfitting. Conventional outfitting is system by system outfitting. It is typified by allocations of resources to ship's systems and does not generally recognize interim subassembly of products, or the common production processes between systems.

3.3 Zone Outfitting. Zone outfitting is a technique which allows augmentation of the production process by classes of problems in order that common solutions can be applied to common problems. It is a means of organizing the work for better control and execution.

3.4 Zone. A zone is any subdivision of a ship which best serves for organizing information needed to support the ship at any stage of the overhaul.

3.4.1 Functional Zone. A functional zone is a subdivision of the ship which includes all equipment associated with a particular system or component. For example, a functional zone might include all piping and pumps associated with a particular tank, as well as the tank itself.

3.4.2 Geographical Zone. A geographical zone is a physical segment of the ship such as a complete deckhouse, a compartment, or portion of a compartment.

3.4.3 Variable Zone. A variable zone is a combination of functional zone and geographical zone which organizes the work by process. It is the zone in which the work is to be done and may include more than one functional and geographical zone. It is also known as a work zone.

3.5 Pallet as a Work Package. Literally a pallet is a portable platform upon which materials are stacked for storage or transportation. The term pallet is also used to indicate a work package. It represents a definite increment of work with allocated resources needed to perform the defined overhaul activity. A pallet is therefore organized by work zone and stage of the overhaul.

3.6 Palletizing. Palletizing is the creation of a work package including job definition, location, software, resource definitions and material definition. It includes integration of zones and processes to achieve an optimum flow of people past the required work.

3.7 Stage. A stage is a band of time during an overhaul in which specific production processes take place. Examples include:

- Prearrival planning/engineering
- Prefabrication
- Disassembly (ripout)
- Open and inspect (replanning)
- Repair
- On-unit assembly
- On-block assembly
- On-board assembly
- Test

3.8 Problem Area. A problem area is an aspect of a particular job which is unique, and therefore requires special categorization. A specialty within a trade is the most common example. However, problem area may also be due to

quantity (large or small) of similar operations, location of the operation, or type of operations (i.e., manufacturing vice assembly).

## 4. PRODUCT WORK BREAKDOWN STRUCTURE

4.1 General. The work required for any large repair project must be subdivided in order to be effectively analyzed and managed.[1] Traditionally, this subdivision has been by ship's functional systems. System orientation is desirable for estimating and early planning. However, system orientation for production planning, scheduling, and execution is inappropriate since it does not reflect the way the work is actually performed. Product Work Breakdown Structure (PWBS) provides a scheme to subdivide the repair/overhaul tasks in the manner in which they are actually conducted.

### 4.2 System Vice Zone Orientation

4.2.1 Schedules. Historically, schedules at NNSY have been drawn on a system by system basis. This technique results in a series of parallel lines which, in theory, are interconnected at each system interface. In practice, the interfaces are insufficient either because they are not properly thought out originally; or because they are lost during revisions to the schedule. Therefore, the end product is a series of parallel lines indicating activities which may, or may not, be interdependent.

In order to resolve this problem the shipyard has turned to PERT type schedules which clearly show interfacing activities. However, the complexity of creating and revising hand drawn PERT schedules is overwhelming. Therefore, it becomes necessary to have a system for creating and/or revising a PERT schedule using ADP equipment.

4.2.2 Job Orders/Work Orders. Job orders, work orders, and procedures, i.e., the paper by which the trades do work, are also written on a system by system basis. A further breakdown usually identifies the job to a lead or cognizant trade. The paper does not usually identify similar work taking place on the same ship, or adjacent/interface work. This results in the real Production Department decisions, such as which tasks to perform together, and when to perform the tasks, being made by each individual trade. While trade supervisors attempt to be objective, it is not unusual for work to be performed on a "first one in" basis. This often results in trade conflicts such as ripout of newly installed items.

### 4.3 PWBS for Overhaul/Repair

4.3.1 PWBS Decisions. To date, PWBS techniques have been applied only to new construction. Figure 4-l has been developed to provide a guide for making PWBS decisions in an overhaul environment. Figure 4-l allows the work to be subdivided categorically by zone, problem area (specialty) and stage. Each category is then examined in relation to the other two. Using this technique it is possible to create a virtual flowlane for the required work. A virtual flowlane may be thought of as an assembly line in which people flow by the work. The virtual flowlane optimizes use of production time by minimizing set up time between jobs of similar skill, and by ensuring that the best possible environment exists when the cognizant trade arrives at the job site. The environment created will provide a safe workplace in which all needed materials are on hand, and all interfacing work has been considered and properly sequenced.

4.3.2 Productivity Measurement. Upon completion of the PWBS analysis described in section 4.3.1 it becomes apparent that one is able to assign a productivity value, or product resource value, to each of the defined tasks. This value will be categorized under the general heading of one of the following.[1]

- Material, to be used for production, either direct or indirect, e.g., steel plate, machinery, cable, oil, etc.
- Manpower, to be charged for production, either direct or indirect, e.g., welder, gas cutter, fitter, finisher, rigger, material arranger, transporter, etc.
- Facilities, to be applied for production, either direct or indirect, e.g., docks, machinery, equipments, tools, etc.
- Expenses, to be charged for production, either direct or indirect, e.g., designing, transportation, sea trials, ceremonies, etc.

Upon assignment of the product resource value it is possible to analyze the availability of resources for each category and determine the impact on the overall performance of work.

## 5. PROMPT SCHEDULING SYSTEM

5.1 General. In order to effectively apply the PWBS technique it is highly desireable to have a real time, interactive scheduling system. Norfolk Naval Shipyard is using the PROMPT System to meet this need. PROMPT was developed by Science Application, Inc. (SAI) of La Jolla, California. To develop this system SAI drew upon hardware and software from similar government applications, and combined these with additional software to provide a dynamic, interactive scheduling system. The system provides integrated schedules at various levels of detail, and allows information to be updated, progressed or modified as required via an on-line interactive terminal.

The present system at NNSY consists of a DEC PDP 11/44 mini-computer with six CRT terminals. The system is operated on a day-to-day basis by scheduling section personnel, and is presently used to create and/or modify PERT chart schedules at various levels of detail.

5.2 Hierarchical Schedules. Shipyard production schedules form the framework for the flow of information between various shipyard functions. Moreover, schedules are the control mechanisms by which planned work packages are conveyed to the work force,.[2] In order to be meaningful to the intended user, the schedule should generally be presented at the level of detail which corresponds to the user's responsibility. For example, the major key event schedule of an overhaul may be interesting to a first line waterfront foreman; however, his real need is a day-to-day sequence of the tasks he must accomplish.

In ‘order to meet the needs of senior management, middle management, and first line supervision NNSY has chosen a top down method of scheduling. Schedules are developed by determining the ship availability dates, the major

milestones, key events and so forth. This process is carried to the lowest level necessary which may be a list of jobs, or a list of tasks within a specific job.

The PROMPT system allows six levels of schedules. Schedules are linked between levels through individual activities. Each of the networks in this hierarchical arrangement is a sub-network which relates to the overall repair plan.

5.3 Schedules by Zone. In order to be meaningful, schedules must indicate the sequence in which work is to be accomplished. The schedule must show all system and trade interdependencies. These fundamental requirements have resulted in three scheduling zones at NNSY. These zones form the basic framework by which the scheduling decisions are made.

5.3.1 Functional Zone. This level of schedule depicts the system functional requirements as they relate to the jobs required to be performed. This schedule creates the basic "windows" in which work may be performed. These windows reflect which systems, or portions of systems, are required to be on line during the overhaul.

5.3.2 Geographical Zone. The geographical zone is simply the physical location of the job aboard ship. Ideally, the jobs are indicated on a composite drawing. However, since-composite drawings are generally not available to an overhaul yard, a "make do" composite is created from the ship's arrangment drawing. There is presently some interest at NNSY in creating composite drawings using photogrammetry. However, this interest has not yet been developed to the prototype stage.

5.3.3 Variable Zone. The variable zone may be thought of as the work zone. It is a union of the functional zone and the geographical zone by the process to be performed.

5.4 Test Schedule. Traditionally, the schedule for testing of ship's systems has been independent from the production schedule. Using the PROMPT system, it is desirable to integrate system tests with production work to the maximum extent possible. This allows testing to take place in the earliest possible window established by the functional zone.

5.5 Progress Reporting/Rescheduling. In order for a real time scheduling system to be effective throughout an overhaul it must have the capability to reflect the status of each job in a timely manner. PROMPT allows the user to enter job progress on a periodic basis (the time period is selected by the user). Upon entry of progress, it is possible to determine impact on the remainder of the network being progressed; and, on netowrks of a higher level. This feature enables the user to reschedule work as the situation changes. Moreover, impact of late finishes or earlier finishes of events may be immediately analyzed and the "best path" to job completion determined.

The real time capability of PROMPT allows the shipyard to perform 'what if' studies in a much easier manner than previously possible. However, yard management has found that while this increased capability is a great advantage, projects must be thoroughly examined prior to initiation in order to efficiently utilize PROMPT resources.

5.6 Management Reports. With the large amount of data stored, in PROMPT it is possible to develop many different management reports. These reports include the following which are adequately described by their title:

- Milestone Report
- Schedule Report
- Work Status and Progress Report
- List of Active Projects

Additional reports include:

a. Bar Graph Report or Gantt Chart which graphically illustrates the scheduled duration of each work item, a Precedence Report which lists all work items in the network and identifies each preceding work item, a Calendar Report which provides a calendar of the network period including those days which the user has declared as holidays, and a Master File Report which is a printout of PROMPT created scheduling files.

## 6. EXAMPLE

6.1 General. The best method to illustrate the concepts previously presented is with an example. Figure 6.1 shows a plan view of the hypothetical ship to be overhauled. Figure 6.2 shows the same ship, with a functional zone representing the Firemain System in the forward portion of the ship. Figure 6.3 shows the first cut at geographical zoning which includes the port Auxiliary Machinery Room, and one half of the Main Machinery Room. The variable zone, or work zone, is shown in Figure 6.4. This work zone has been determined by analyzing all work in the machinery space using the PWBS system.

6.2 Specific Jobs. For the purpose of this example assume that the following specific jobs are to be performed in the variable zone shown in Figure 6.4.

JOB ORDERS

1. Replace 9'-0 level grating
2. Replace firemain piping FR 100-102
3. Replace demineralized water pump and motor
4. Calibrate gauges system 1
5. Calibrate gauges system 2
6. Calibrate gauges system 3
7. Add light frame 103-104 S/A 1000
8. Renew pipe and valve main feed system FR 100-102
9. Add vent duct S/A 2000
10. Open/inspect/repair valves system 1
11. Open/inspect/repair valves system 2
12. Open/inspect/repair valves system 3
13. Open/inspect/repair valves system 4
14. Open/inspect/repair valves system 5
15. Add shock support and modify demin water pump foundation S/A 3000

6.3 Tasks Required. In order to accomplish the jobs listed in section 6.2 the tasks shown below must be ‘performed. Thse tasks have been organized by stage; i.e., Planning and Engineering, Procurement, Open and Inspect, Secondary

Procurement, Repair, On Unit Assembly, On Board Assembly. This has been done by proceeding through the PWBS process as outlined in Figure 4.1, which results in the breakdown of:

## PLANNING AND ENGINEERING

Define jobs from customer.
Perform production planning.
Write job orders or procedures.
Define material
Schedule work

## PROCUREMENT

Procure material and fabricate demin water pump foundation.
Procure material and fabricate main feed system pipe.
Procure material and fabricate fire main system pipe.
Procure material and fabricate vent duct.
Procure material and fabricate light assembly.

## RIPOUT

Remove insulation
Remove demineralized water pump and motor
Remove MN feed pipe assy
Remove 9' -0 level grating and demin water pump FND
Remove AUX salt water PPG
Remove fire main
Remove gauges
Remove 6" demin water pipe FR 100-103
Install temp staging @ 9' -0 LVL
Cut temp access

## OPEN AND INSPECT

Open/inspect system 1, 2, 3 valves, flow path A
Open/inspect system 1, 2, 3 valves, flow path B
Open/inspect system 1, 2, 3 valves, flow path C
Open/inspect system 4 & 5 flow path B
Open/inspect system 4 & 5 flow path C

## SECONDARY PROCUREMENT AND REPAIR

Procure material identified by open and inspect stage.

## REPAIR/ALTERATION

Perform all repairs and alteration work aboard ship and off ship such as valve lapping, component maintenance, etc.

ON UNIT

Assemble demineralized water pump unit

ON BOARD

Reassemble system 1, 2, 3 valves flow path A
Reassemble system 1, 2, 3 valves flow path B
Reassemble system 1, 2, 3 valves flow path C
Reassemble system 4 & 5 valves flow path B
Reassemble system 4 & 5 valves flow path C
Reinstall system 1 gauge, flow path A
Reinstall system 1 gauge, flow path B
Reinstall system 1 gauge, flow path C
Install vent duct
Install MN feed pipe assy
Install fire main piping assy
Reinstall ASW piping
Install demin water pump unit and connect pipe
Remove staging Clean and paint bilge
Install 9' -0 LVL grating
Close access cuts
Install light
Relag MN FD and demin water PPG ABV 9' -0 LVL
Clean and paint 9' -0 LVL to 22' LVL

Once the PWBS technique has been completed a PERT schedule for the tasks is generated, a portion of which is shown in Figure 6.5. The schedule is then progressed, and tasks are rescheduled *as* necessary, as work progresses.

## 7. EXPECTED PRODUCTIVITY IMPROVEMENTS

7.1 Current Improvements. Presently, the PROMPT system is in use for planning and scheduling of a complex overhaul of the propulsion plant on a CGN. Schedules have been produced with the computer which have resulted in a significant savings in the manual drafting time previously required to produce a schedule. However, greater savings have been achieved when it has become necessary to revise PROMPT schedules. A revision with PROMPT takes only minutes, where the hand drawn revision would take days.

7.2 Expected Improvements. While there have been productivity improvements in scheduling, the greatest improvement is expected in the Production Department waterfront trades. The virtual flow lanes created by the PWBS process will produce an efficient use of trade resources in that work will be performed in an orderly manner which has been thought through objectively prior to arrival of the cognizant trade at the job site.

1. "National Shipbuilding Research Program - Product Work Breakdown Structure" U.S. Dept. of Commerce, Maritime Administration

2. "National Shipbuilding Research Program - Outfit Planning" U.S. Department of Commerce, Maritime Administration

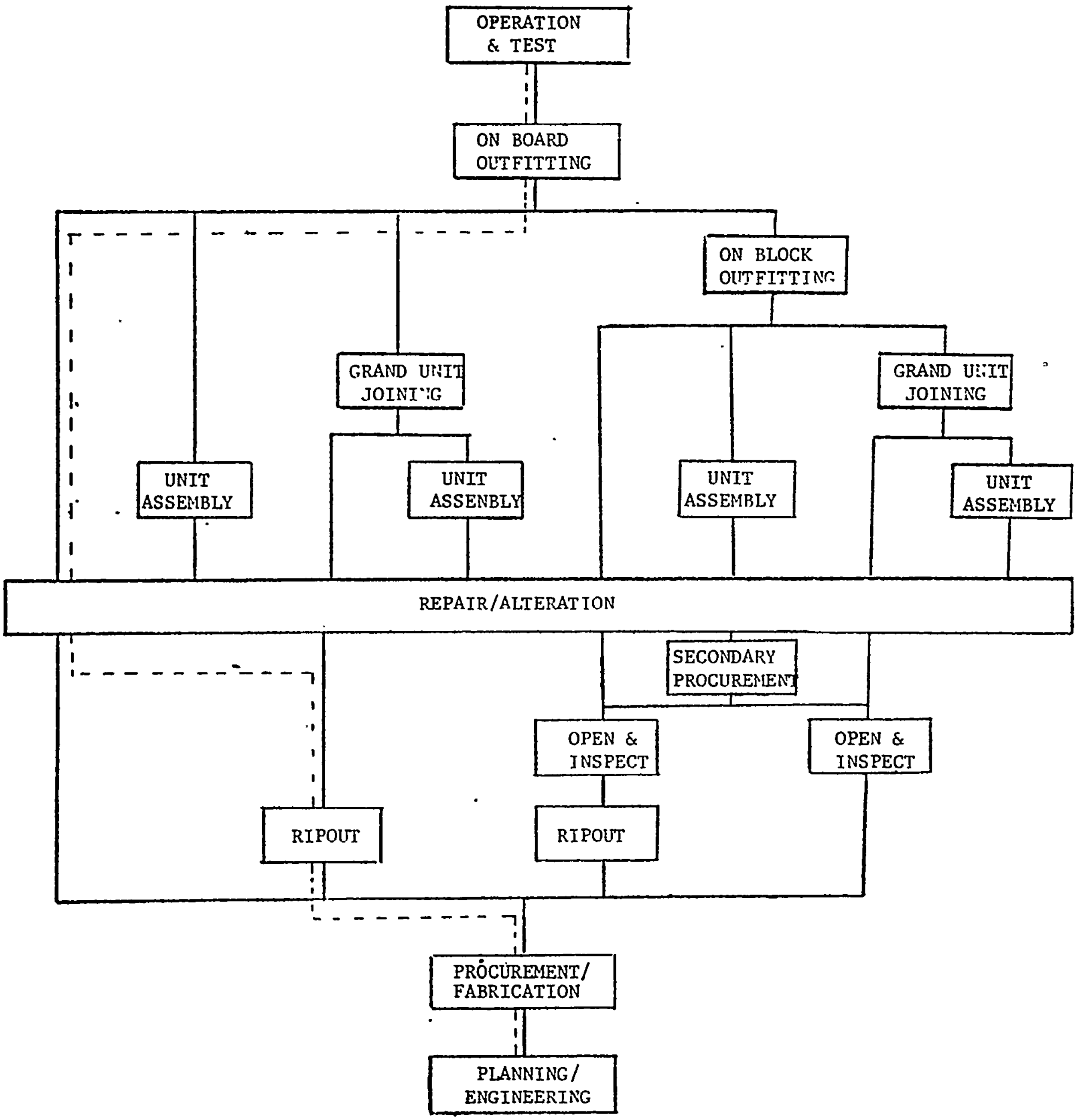




FIGURE 4.1
SH 1

| PRODUCT ASPECTS | | |
|---|---|---|
| ZONE | PROBLEM AREA | STAGE |
| SHIP | DECK<br>ACCOM.<br>MACH<br>NUCLEAR<br>ELECT.<br>ELEX/WEAP | OPERATION & TEST |
| ON BOARD DIVERSION | SIMILAR WORK IN SML VOL.<br>SIMILAR WORK IN LRG VOL.<br>SIMILAR WORK IN HIGH SKILL | REASSEMBLY |
| BLOCK | COMPONENT IN LARGE QUANTITY<br>COMPONENT IN SMALL QUANTITY | REASSEMBLY |
| GRAND UNIT | LARGE UNIT | WELDING<br>UNIT JOINING |
| UNIT | LARGE SIZE UNIT<br>SMALL SIZE UNIT | WELDING<br>ASSEMBLY |
| COMPONENT | LARGE/SMALL QUANTITY<br>SPEC-IALTY<br>INTER-FACES | |
| ON BOARD DIVERSION | BY SPEC-IALTY<br>ITEMS IN LARGE/SMALL QUANTITY | INSPECT/REPORT<br>DISASSEMBLY |
| ON BOARD DIVERSION | BY SPEC-IALTY<br>ITEMS IN LARGE/SML QUANTITY<br>INTERF. | SORTING (DEPALLETIZING)<br>DISASSEMBLY |
| COMPONENT | IN HOUSE MANUFAC<br>OUTSIDE MANUFAC<br>BUY<br>REQ. FROM STOCK | PALLETIZING<br>MANUFACTURING<br>MAT'L REQ. DEFINITION |
| SHIP | DECK<br>ACCOM.<br>MACH<br>NUCLEAR<br>ELECT<br>ELEC/WEAPS | PREARRIVAL INSP. REPORT<br>SHIPALTS<br>TECH WORK DOC. |

FIGURE 4. 1
SH 2

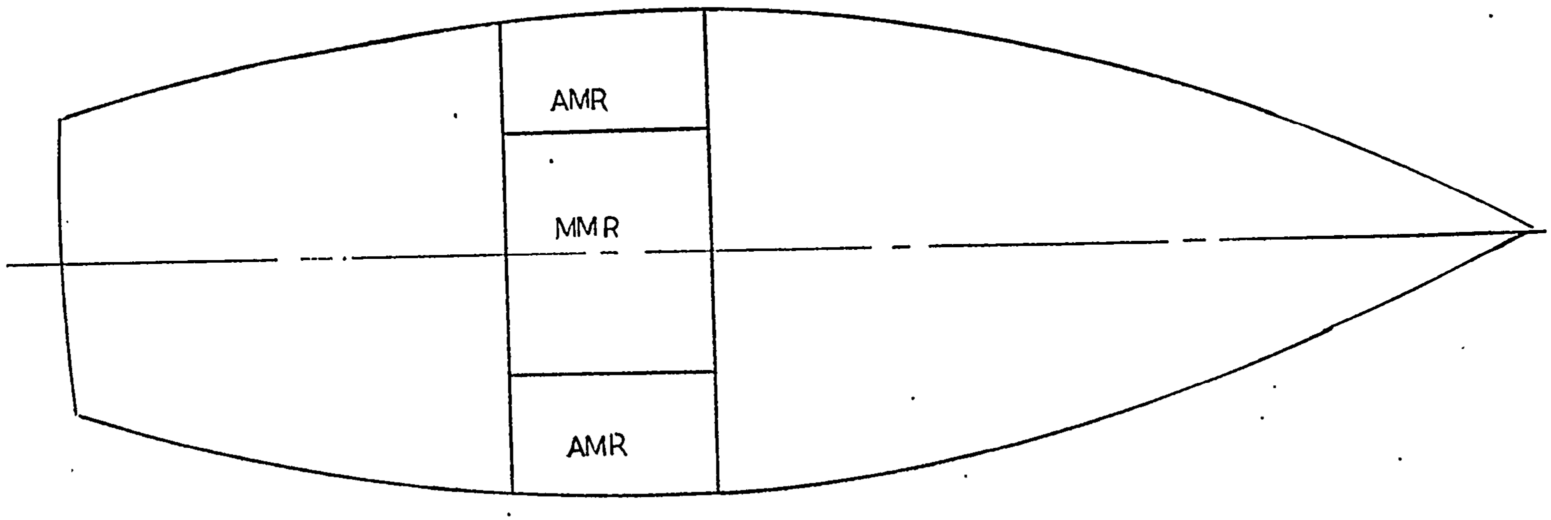



FIGURE 6.1

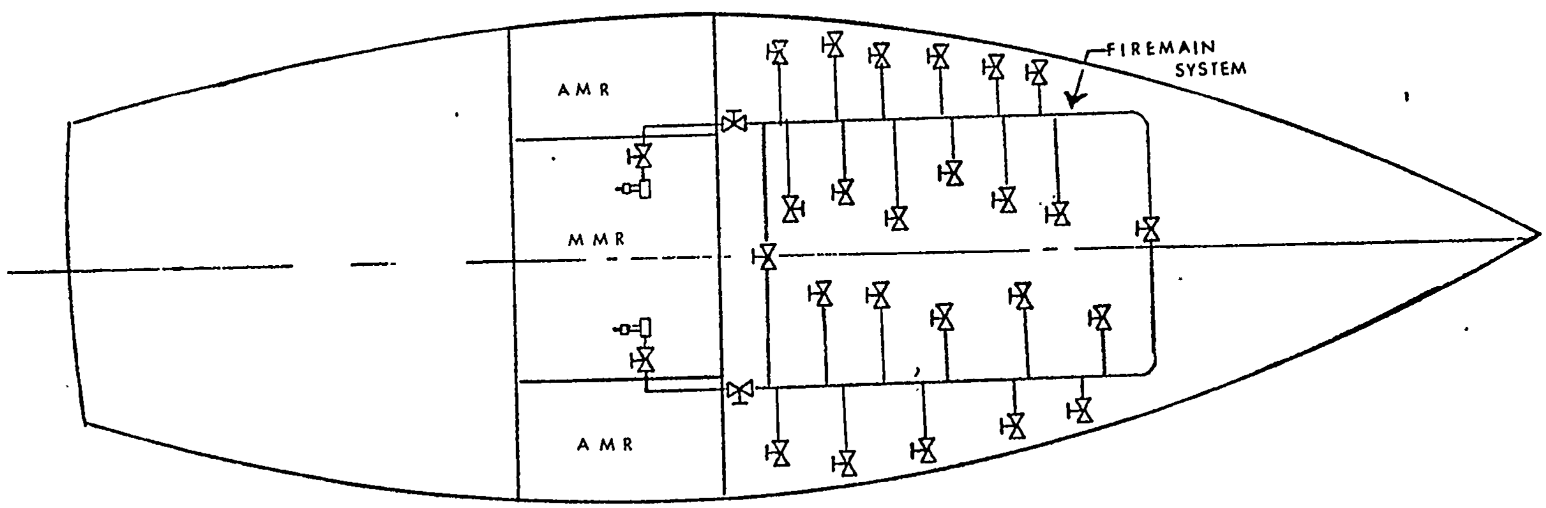



FIGURE 6.2

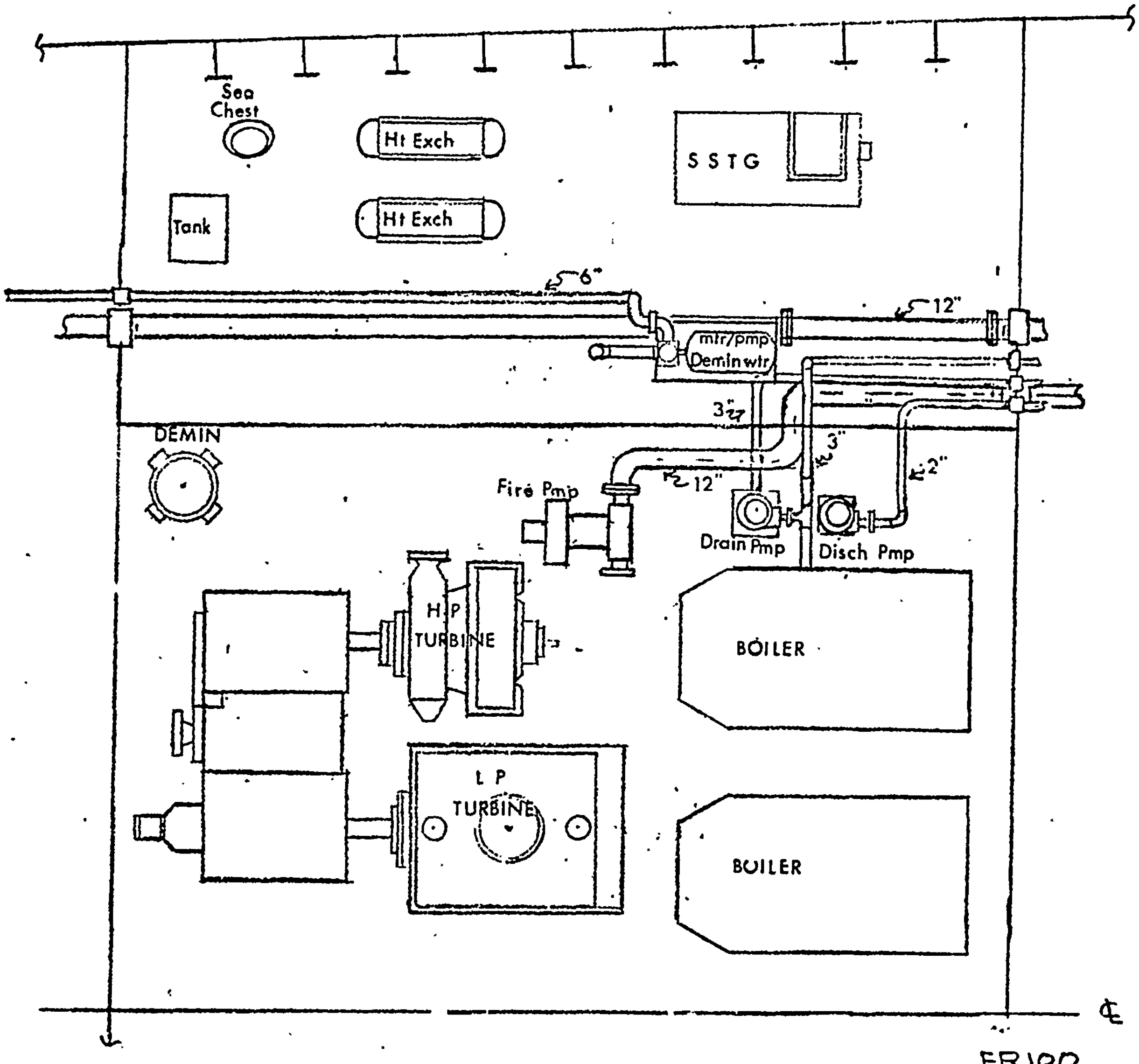
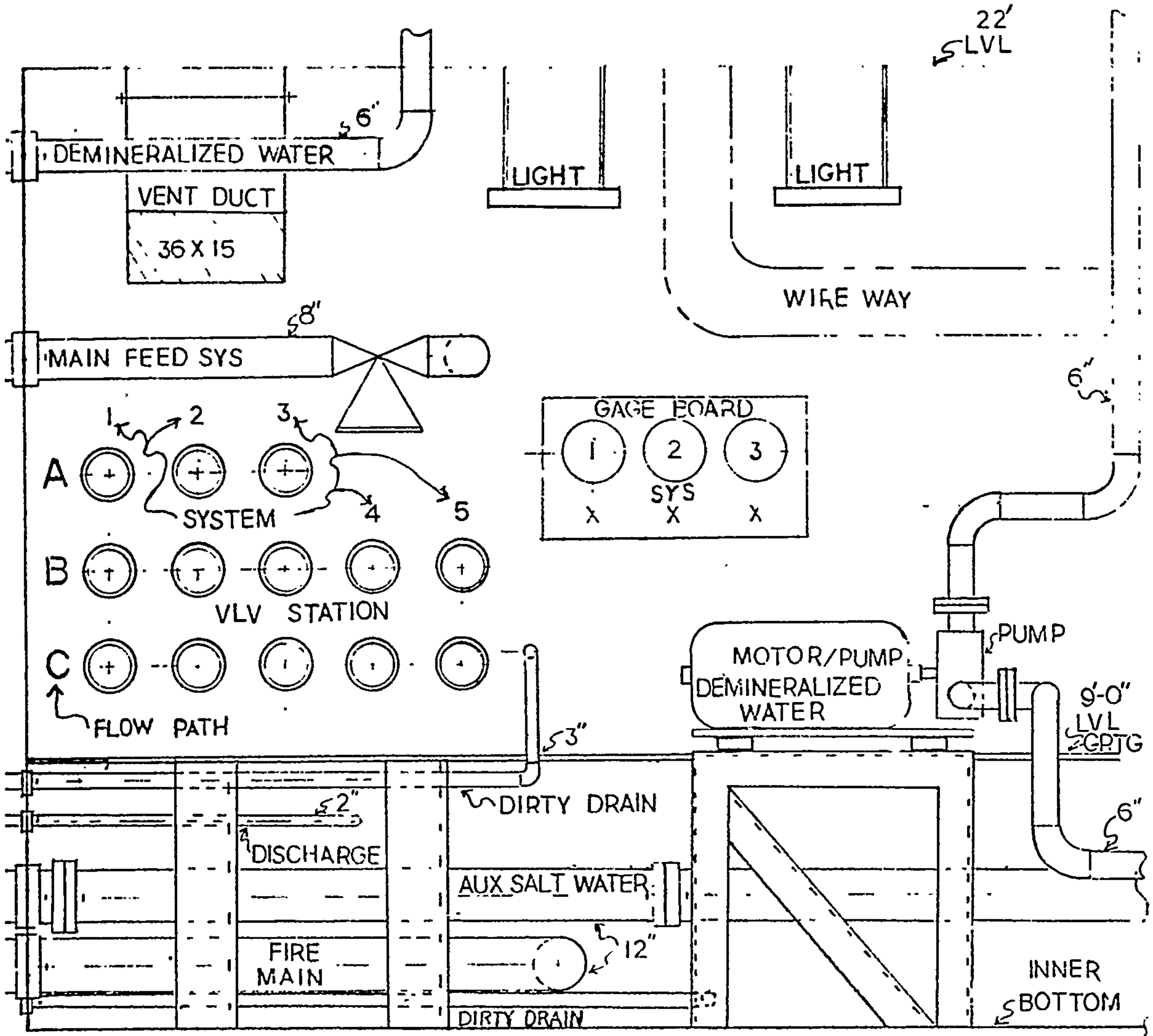



FIGURE 6.3

PLAN

FWD →




ELEVATION (LKG INBD)

FIGURE 6.4

FR 00 FR 101 FR 102 FR 103 FR 104 FR 105

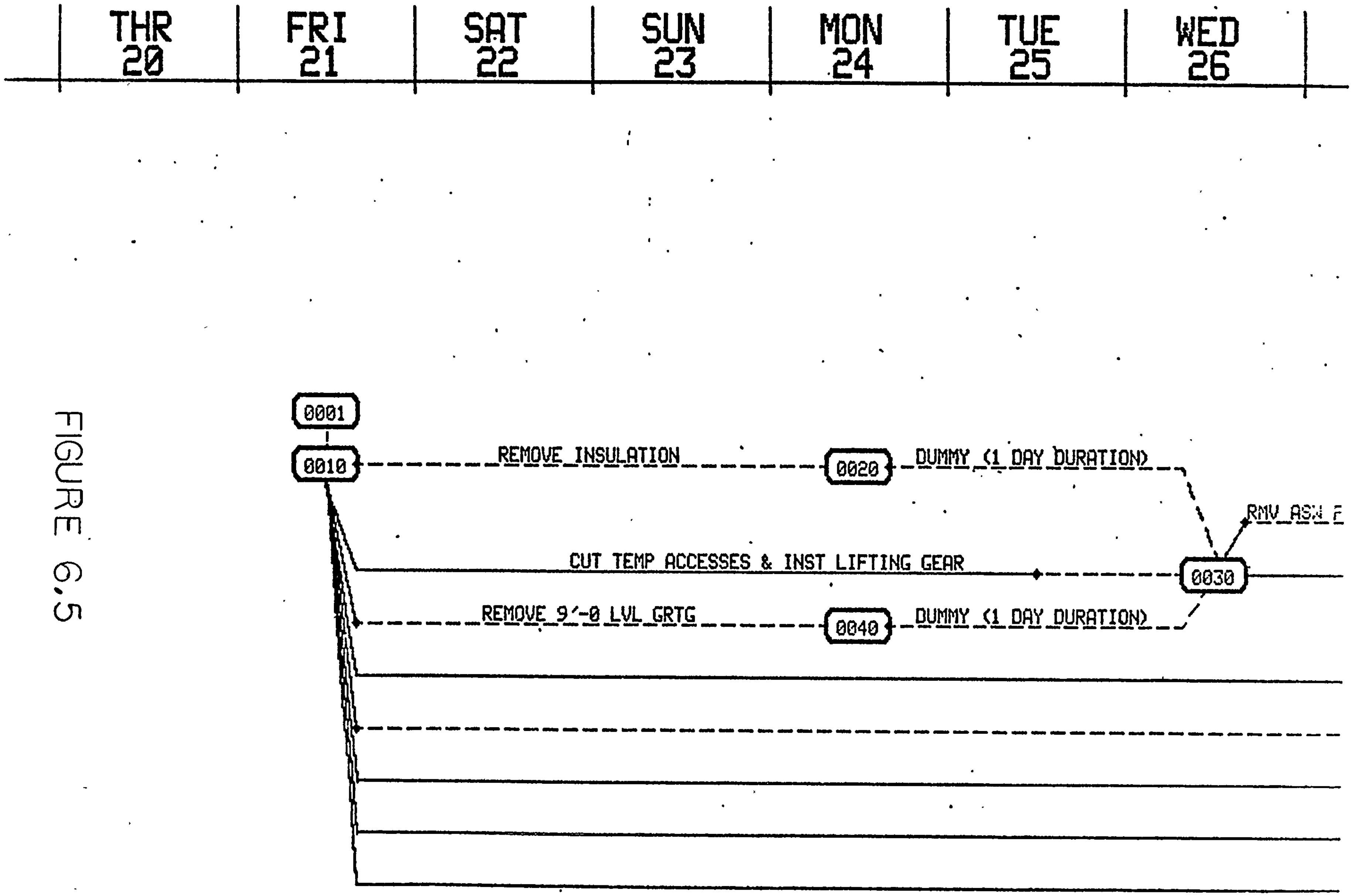

THR 20
FRI 21
SAT 22
SUN 23
MON 24
TUE 25
WED 26
0001
0010
REMOVE INSULATION
0020
DUMMY (1 DAY DURATION)
CUT TEMP ACCESSES & INST LIFTING GEAR
0030
REMOVE 9'-0 LVL GRTG
0040
DUMMY (1 DAY DURATION)

FIGURE 6.5

# HULSTRX: A U.S. NAVY STRUCTURAL DESIGN MODEL

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# HULSTRX- A U.S. NAVY STRUCTURAL DESIGN MODEL

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ABSTRACT

The concepts and status of the HULSTRX development along with a discussion of its utility in the rapidly changing U.S. Navy ship design environment are presented. HULSTRX provides for definition of ship structure at preliminary and contract design levels in terms of absolute geometric data and relational component data. Relational structural component definitions allow for quick design changes, and absolute geometric description of the hull surface can be independently defined. Application routines will enable designers to efficiently produce design drawings, various structural and geometric analyses, and interface with design or product models of other systems.

IREAPS PAPER ON HULSTRX - A U.S. NAVY STRUCTURAL DESIGN MODEL

## HULSTRX - Present Status

The dual purpose of this paper is to report on the work that has been done in adding the interactive Structural Scantling File (SSF) to the Hull Stucture (HULSTRX) program and to outline the work to be done this fall in making the SSF an interactive design tool with graphics capability. In addition, the outlook of the U.S. Navy on the use of computer aided design tools will be reviewed, and some thoughts will be presented on the major considerations of a general data base design of the future.

Several papers have been presented on the HULSTRX progress during the last few years. See References 2, 3, and 4. These papers describe the background for the development of HULSTRX.

HULSTRX was last reported on in June of this year (Reference 4). The addition of the Ship Structural File to the HULSTRX programs has given the structural designer the capability to interactively add structures to the geometry of the ship, and to have structural drawings produced both on a graphics terminal as well as on a plotter.

The workings of the SSF program will be discussed a little later. The way in which it and the extensions to it interface with the existing HULSTRX files are shown on Fig. 1. SSF is essentially a stand-alone program that will create its own interactive database in which the structural details are stored. These details describe the structure with respect to type, material and extents. The traces on which they are to be placed are described in geometrical terms on the Design Geometry Library (DGL) file created by HULSTRX.

The next step in the direction of the generation of drawings is to add capabilities to the SSF Program so that drawings can be generated. Such drawing will first be displayed on a graphics screen and later on on a plotter or drafting machine. This effort is under way and will be completed by the end of the year. (Fig. 2) It is recognized that HULSTRX also should be converted to an interactive design tool. Such an effort may be started next year.

HULSTRX is the structural portion of Computer Supported Design (CSD). The CSD system is a set of linked individual computer programs which assist the cognizant engineer in developing a ship design. The shipbuilding industry is in a changing posture. The change is not just rhetoric, but a continuing effort. The needs of the industry should cover the entire spectrum of ship design, construction, overhaul, and repair. These needs have been recognized for many years but the computer hardware and software, and people that are eager to make the change, have recently became available to the industry in the numbers needed to exercise the change. The method of design must change and the time required to complete a design must be reduced. Since the use of the computer was accepted as a tool of the industry, the way to control it

had been somewhat lost. Manual methods allowed three (3) to eight (8) design studies for a single ship design to be firmed up. With the computer, the studies go into the hundreds and the design process has grown, not decreased. Management of a computer-assisted design is a must if the real value of computer assistance is to be realized.

Design for design's sake should no longer be tolerated with computer-assisted designs. The process must be a continuous effort and build from the previous work done and not start over for each phase of design and construction. The manual method gave us little option, but that has changed. The ability to work from structured programs with a data base allows for true standards. The control of time, schedule, cost and quality can now be logically accomplished with a systematic approach.

The needs of the industry should be keyed to professional training. The people presently studying engineering and even many trades are exposed to computers and the mystique of how they work is gone. Home computers, video games, and TV graphics have set the tone of the country. The youth of the country are ready for a computerized industrial base and ship designers and builders should be ready.

HULSTRX is one of the tools being developed to meet the challenge. The system is being built on the strength of other programs and the needs of the user. HULSTRX has many requirements; no thought was given to develop a special stand alone system. HULSTRX as presently defined is about sixty-five (65) percent complete. Based on the original program plan, the present status should be ninety (90) percent complete. This is a true indication of how the needs of a system grows as user's.

HULSTRX is a relatively new program when one considers the time it takes to develop a system of this nature. The major goal is to computerize the process and to develop computer graphic drawings from preliminary through contract design. In-house designs that are done by the U.S. Navy without contractor support are done with engineers. The Surface Ship Structures Division has only three (3) types of people working in the office; engineers, engineers-in-training, and engineering aids. The engineers are full time employees that selected the Surface Ship Structures Division as their main area of employment. Engineers -in-training are the young engineers that are starting full time careers with the Navy. They spend four (4) weeks in each code as part of their exposure to the various discipline in the NAVSEA design area. Engineering aids are students, usually with one (1) to three (3) years college that work summers and long holidays. This limited description is given to show the need for a special system which will be able to carry a larger workload, thus reducing personnel needs.

Most people that work in the design area must realize that engineers do not like to draw drawings in the formal sense of the word. They will sketch structures, develop load diagrams, and spend numerous hours developing a finite element model but that all falls within the engineering arena.

HULSTRX took into account these user constraints into account in the planning and development. The basic development *was* the line definition of a shell expansion; this was selected as a keystone requirement and when accomplished would allow for the development of the simpler surfaces such as decks and bulkheads. The next phase was to develop the scantling file that is the subject of this paper and will be covered in detail later on.

Having a computer drafting program as support, *a* structural engineer should directly interface with his engineering tools. One of the major programs that is used by the Navy is the Structural Synthesis Design Program (SSDP). This program designs all longitudinal structures for Navy type designs in the hull of a ship based on standard Navy design criteria. The output is of a general nature and requires interpretation. Presently under development is the interface of HULSTRX and SSDP. The interface program, when completed in early 1983, will allow most longitudinal structure to be input from a design tool to *a* graphic tool without a great deal of manual interface. The engineer still makes all the engineering decisions. The program will work both when a design is near completion and all openings or holes are known, as well as from HULSTRX, when data will be fed to SSDP and all factors of safety can be checked. Under all present design methods, this is only selectively done. Planned FY 83 developments will expand the use of the program with the development of a neutral finite element file from HULSTRX DGL. The mesh may require refinement but the basic structure will be available in a format that will allow expansion as required-and eliminate the need for a great deal of mundane development work. Another interface is a program similar to SSDP that will do commercial design hulls that are required by the Navy. The need to interface all aspects of conventional shis is critical as ninety-five (95) percent of shipbuilding dollars *are* in this area. The idea of making a program that will do special ships in all materials is ideal but not practical. The unique loading and materials used in Hydrofoils, LCAC, SES, and Minehunters, are not needed in a standard program.

## Ship Structural File - Program Design

This section describes the design considerations and their implementation in the making of the interactive Ship Scantling File (SSF). In addition, some general thoughts on the trend that is being persued in this kind of work are outlined.

The SSF is essentially a file containing the structural data that can be edited interactively. As a subsequent step, the data in the SSF will, together with the data in the DGL file, be used for the generation of structural drawings for a preliminary and contract design.

The starting point for the SSF is an existing Design Geometry Library (DGL) file. A separate program will make a skeleton SSF based on the structural members in the DGL file. The subsequent editing of this SSF is accomplished by means of programming that enables a user to insert, modify and delete data for structural members represented in the files, as well as add new members.

The structural parts are grouped together as surfaces. Some of the data entered into the file applies only to individual surfaces; some apply to whole surfaces as such.

Apart from the programming that performs the editing functions there are a few utility-type functions that are used for purposes such as starting a new SSF, packing a SSF, creating hard copies of the contents of an SSF, creating shapes file and transfer of data between different types of computers.

Program Design

The major considerations that governed the design and coding effort of this programming development were:

1. Interactivity and user friendliness. Computer programs have frequently been difficult to use. Some computer experience was usually required in order to make runs for the purpose of performing many engineering-type calculations by means of a computer program. The SSF can be edited by personnel without any computer experience. It has also been designed for interactive use and the results will be right there for the user to see.

   The editing program and some of the utility programs are command driven. As much error checking as possible is done when commands and associated data are keyed in. Unacceptable commands and data are flagged immediately and the user can re-enter the proper input. Help functions are also available. Any command may also be terminated by simply entering a $ in the command string.

2. Program transportability. The Navy uses a number of different computers and conversion problems were sought avoided to the greatest extent possible. The development was done on a PRIME computer and then put up on a VAX 11/780.

   The machine-dependent functions such as reading time and date from the computer system as well as some file accessing were isolated in a few subroutines. In addition the initialization of logical unit numbers was all done in one place. As a result of this effort the conversion to the VAX was accomplished without any difficulties.

   Another aspect of transportabilty is the way in which the files used during a run are opened and closed. Both PRIME and VAX have a Command Processor Language which handles that aspect of data management. In order to make the use of the programs as easy as possible, the files could have been opened and closed from within the programs during the run time. Such an arrangement would, however, have required machine-dependent FORTRAN coding.

3. Rapid file access. This aspect is really an extension to the user friendliness considerations, as sluggish response due to slow file access will frustrate users and make the program less acceptable.

With this requirement in mind the file access had to be random rather than sequential. However, as a user would deal with one surface at a time, it was decided to lay the file out such that it would be searched for specific items, first by surface and then by structural component within the surface. This *arrangement* made the programming much simpler than would be the case if a file organization with a hashing mechanism for placing and finding records had been implemented.

4. Since a number of structural members on any one surface will be equal with respect to shape and size, or shape only, the ability to copy data from one member onto the record of another was considered to be important. Consequently, data already entered for one member or for a whole surface can be transferred with ease to another member or surface.

5. Structural members will in most cases be cut from standard shapes. There are presently about 300 such standard shapes available from steel mills in the U.S. A file with such shapes has therefore been made, together with the necessary programming to access this file so that the user only need specify a shape number. The abbreviated description of the shape together with web and flange dimensions will be fetched out of this shapes file and stored with the structural member.

   In some instances special shapes or built-up members will have to be used. The file with standard shapes can be expanded to accomodate such data as well so that a designer will have as easy access to such data as he has to data describing standard steel mill shapes.

6. Protection of data, from unauthorized use as well as accidental destruction, was yet another concern. The data files can therefore be password protected. Whenever opening a datafile for working the user will be asked if a copy of the file to be edited is wanted so that if a run is terminated improperly only that work done since the beginning of the run will be lost.

   *In* fact, whenever writing a record to the file, new or updated, administrative data pertaining to the surface being worked on as well as the whole file as such is updated. The chances of losing any data due to a computer crash are very small. If the option to have the file copied at the beginning of the run is exercised very little would be *lost*.

Utility Functions

A number of Utility functions were provided with this programming package.

The starting point for a Ship Scantling File is an existing DGL file as generated by the HULSTRX program. Such a file contains all geometrical data for a ship, or part of a ship.

A stand-alone mainline program, SFNEW, will scan a DGL file and create a skeleton DDF. Every surface within the DGL file will be represented on the SSF and within every surface all structural traces will be represented' on the SSF. A trace may result in several structural pieces as the scantlings may change along a longitudinal or a frame. The structural traces are recognized by their names. On a DGL file there will be geometrical information that does not represent structures. Such data will not be represented in the SSF.

Plates will also be represented in the SSF. In a sence a trace can be likened to a plate strake. Such a strake can then be broken down into several individual plates.

SFNEW need only be run once for every SSF file. It generates records for all surfaces and for each structural trace it finds. In addition there will be one plate record for each surface. No specifics as regards structural data will be associated with the surfaces and the structural parts. In a sense, all records will be empty.

By initializing an SSF this way, a lot of work is saved in creating the records. This process lays out the file. Deletions and additions can be done at any time later on.

Once a SSF has been established, it will be necessary to manage it. The functions that are required are checking of password, change of the password, packing the file and producing hard copies of it. The program that does this is named SFUTIL and is command driven just as the Editing program itself. Only the person, or persons, that are authorized to perform file management functions are supposed to have access to this program.

The library of standard shapes that will be referenced can be updated by means of a stand-alone program named SHAPES. The main function of this program is to expand the file of standard shapes *to* include Special and built up shapes. It is also to be used for the purpose of modifying *or* removing special shapes. SHAPES is command driven, just as SFNEW. It is not expected that SHAPES will be used very often.

Apart from these utility functions, there are two additional programs that *exist* for the purpose of moving data for the DGL and SHAPES files between two computer systems. All files used by any program are binary, i.e. no data conversion from internal representation according to a FORMAT statement occurs when reading from a *file* or the other way around, when writing to a file. Thereofore, in order to transfer files between computer systems the binary files are converted to data in ASCII format. *Files* on the system from which the transfer is to take place will be converted from binary to ASCII and then transferred via tape. On the receiving system such ASCII files will be converted back to binary.

The program that converts data from a DGL file was made for the HULSTRX program and only put up on the PRIME. One minor modification had to be made inorder to make this program work on both PRIME and VAX computers. This program performs the conversions both ways, i.e. either from ASCII to binary or the other way around.

A similar program was made for the purpose of transferring data for the SHAPES.

## Editing Program

The main editing progran is named SFEDIT. It is programmed in FORTRAN and makes use of system subroutines for reading time and date as well as accessing the SSF. The reason for using a system subroutine for file read and write rather than standard FORTRAN random access read and write statements is that processing on the PRIME is much faster by using the system subroutine. However, it is perfectly possible to use the FORTRAN statements. The VAX implementation was done that way. It is not possible to use both access methods on a PRIME file as there is a little difference in the way the data is laid out.

Two concepts need be explained before the editing functions are outlined:

Current — The record or records being worked on are the current record or records. If a surface as such is being worked on, supplying new, replacing existing data or deleting data, then the surface is current. All functions relate to the surface. If the surface is deleted, i.e. removed from the file, then all records for plates or structural pieces belonging to the surface as well the surface record is removed.

When a plate or structural part is current, then both the surface and the plate or piece are current. However, when such a plate or piece is removed the surface and all other plates and pieces under it remain as is.

Active — Data describing the surface and its individual plates or pieces are entered by means of some of the commands described below and placed in a buffer. The data in this buffer is referred to as the active data. Whenever a record is filed or stored data from the active buffer is written out to the record on the file.

The active buffer may contain data pertaining to *a* surface, to a plate and to a structural piece. During the filing operation only that which pertains to the type of record is written to the record on the file.

The editing functions that *are* provided in the editing programs are these:

BOUND — Prompts for bounding data for a surface or plate or structural piece.

CLEAR — Clears all data from the active buffer.

DELETE — Deletes the current surface with all associated plate or structural pieces or individual pieces only.

END Terminates the editing session.

FILE Writes active data on current record.

GET Reads specified record from the SSF.

IDNAME Lists standard 6-character identifiers.

INTERSECT Prompts for intersection data for the current surface.

LIST Provides listing of specified type of records which may include all surfaces in the file or all plates or structural pieces within the current surface.

MATERIAL Prompts for the material type.

NEXT Displays next logical record on SSF.

ORIENT Used to define orientation.

PIECE Finds and displays specified piece.

PLATE Finds and displays specified plate.

SCANTLING Prompts for plate/shape scantling.

SET Makes parameters of current SSF record active, i.e. moves data from file record to active buffer.

SHAPE Finds and displays specified shape.

STATUS Displays non-zero active data for the kind of record being current.

SURFACE Finds and displays specified surface.

All the commands can be abbreviated to the first two letters, i.e. FI for FILE, MA for MATERIAL, PI for piece, etc.

Most of the commands will read the associated data from the same line as the command and will prompt the user for that which is not found. Some commands will prompt for individual data as it would not all fit on one line.

There is also a HELP function which will list all the commands with a brief description of what they do. If a command is not recognized the user will be given -a message to that effect.

All data read will be interpreted by the program rather than a FORTRAN FORMAT statement which may cause program termination if the data is mistyped. By having it this way, errors made in typing can be corrected by retyping.

## Future Data Base Design - Considerations

This section outlines the requirements of a future data base based on the present experiences.

The present state of the programs used in ship design and manufacturing in the U.S. and indeed around the world is that interactivity such as is now possible with multi-user operating systems on very reasonable mini-computers is not fully taken advantage of. A number of programs that where written in the days of cards and batch processing are still around.

Special interfaces have been and are being made to allow output from one program to be used as input to another. Many existing programs are difficult to use due to input requirements designed for cards with little or no concern for other uses, or for how the input could be made flexible. Another way of expressing this would be to call it user unfriendly.

Transfer of data between different types of computer equipment is frequently less easy than it is possible to make it. This applies in particular to systems with reasonably sophisticated data base designs. In particular, it is not possible to down-load portions of a data base to a smaller computer over a dial-up communication link for off line work and then to transfer the results of such work to a larger data base over the same dial up communication link at a later stage.

Another aspect of present day software technology is that some programs have to access different data files in different ways in order to get at all the data that is needed for a specific application.

Significant improvements in the ease of use of programs can be made with a relatively small effort towards making existing programs truly interactive and in designing data base systems that will enable transfer of data between different application programs and between different computer equipment. The rest of this section is devoted to some of the design requirements of such a data base.

The main requirements of such a data base are as follows:

Files — Sequential files are so slow to access in any other way than record by record as they occur that the only acceptable way is random access. Such an access will in most instances require a hashing mechanism, although it is possible to design access methods that will use data from a previous record to calculate the position of the next one to be examined.

A hashing mechanism imposes a software overhead and will require more physical disk space than a sequential file due to the fact that some record spaces will not be filled. However, it is the best way to find where to put a record and where to find it again later in as short a time as possible. The response from the system is extremely important when a file is being accessed interactively.

There are other ways of placing records in a direct access file than hashing, but the programming overheads are usually as large and the response would be slower because it would involve some searching in a register.

Records

The records to be used must necessarily be of varying length and they must not be laid out in just one fixed way. It is possible to store one or a couple of keys with the record that can be used *to* indicate both lay-out and length.

The requirement of having records of varying lengths makes it necessary to have an index area which must remain in the file at all times. Each record will have its name entered here together with information such as time/date stamp and pointers to where the record data is stored. As records are entered, the file will grow. Since the records are to be of varying lengths, they must consist of a number of blocks, each of standard length. A record will therefore consist of one or more such blocks apart from the entry in the file register.

The position of a record in the register will be determined by a hashing mechanism. If all records were to be of one size, then the file could be initialized with a number of such record. The name, date/time stamp and other administrative data could reside in the record together with the actual record data.

Access

There are two aspects of access. It should be easy to store and retrieve data in the files for just about any program and it should be possible to transfer records between computer systems over dial-up communication lines. In particular, it will become important to be able to down-load only a part of a data base to a smaller stand alone computer and then to up-load the result of work done on such a system to the host computer.

There are far too many programs today that still operate independently of related programs. Programs written for the computer equipment of yesterday have been converted to read from a file rather than a card reader and to write to a file instead of a line printer. Such programs were made with little or no concern for other uses of the output. Some were made to produce a deck of cards, or a file that could be used by other programs.

The more advanced systems such as CAD/CAM programs were made with highly specialized data bases that were difficult, if not impossible, to access for uses other than those associated with the system for which it was made.

Interactivity In going from batch oriented programming systems to interactive systems, the old databases were frequently retained or slightly modified. The time in accessing such data bases frequently were too large for the system to be accepted by users. Rapid response from an interactive system will depend on the data base design as far as retrieval of data is concerned. Sluggishness in such responses will make a system less acceptable.

The second aspect of interactivity is the way in which a system lets users enter data. This has no direct bearing on the data base design, but deserves a few words in this context. Well designed screen layouts with prompts can be very helpful. Error checking at the earliest possible stage is also important in that it lets the user recover as early and as often as possible.

Sharing Data Down-loading parts of a data base to a stand-alone system will become more desirable as the hosts themselves become smaller and smaller. A number of functions can be performed by stand alone micros which can go in and fetch data for a day's work. At the end of the day the result can be put back into the databank in the host. Over a dial-up line, independent work stations can be set up in a different location and reduce the demand on CPU in a central computer. At the end of a task the result can then be transmitted back to the host.

The result of work in an independant workstation may result in-additional records or modification of those that were down-loaded. The modified ones will replace the original ones when the result is sent back into the host computer.

Another reason for communications is that a data bank or part of one may be transferred between computers, thus avoiding delays associated with sending tapes or floppy disks through the mail.

The communication interface at a host computer can be written as an extension to the data base programming. It will be required to fetch a specified record from a file, possibly do some conversions and then transmit bytes down the line. The records moved that way will be put into a data base in the receiving system. The specific file into which they will go need not be the same size as that

in the sending system. When a record is entered into any such system, its name is hashed and the result of that hashing will be a fraction as well as a specific number for the file into which it is to go first. For subsequent transfers, the fraction will be used to determine the place in any data base.

Portability — The software needed to implement a scheme such as has been outlined above needs to be portable if it is to be implemented on several types of computers. Efficiency will, however, demand that some parts will be accomplished by means of system subroutines already available for some systems or by assembly on others. The important portability aspect here is well-defined specifications so that certain pieces of software such as file handling, file access input routines and communications can be implemented on a number of different types of computers -- micros, super-micros, minis and mainframes.

Data Safety — A data base system to be put in place on several physical computers and linking these by telephone lines must necessarily have built-in safe guards against the loss of data whenever a run is terminated improperly due to a line being lost. There are several design features that can be built in to minimize the loss and to make recovery as painless as possible. Just to indicate the kind of features that might be designed in it can be mentioned that a continual updating of all administrative data on the physical disk file will minimize the loss. A recovery can be made fairly easy by keeping one record that at all times indicates the very last record put in place and some data regarding it.

Security — By making a data base accessible from several locations it will be necessary to provide some security in the form of passwords and scrambling. These measures are meant only to make it difficult to access data that should not be available to just anybody. They are not meant to protect classified data. However, passwords and scrambling can be a considerable deterrent to anyone attempting to see what kind of data is in a file.

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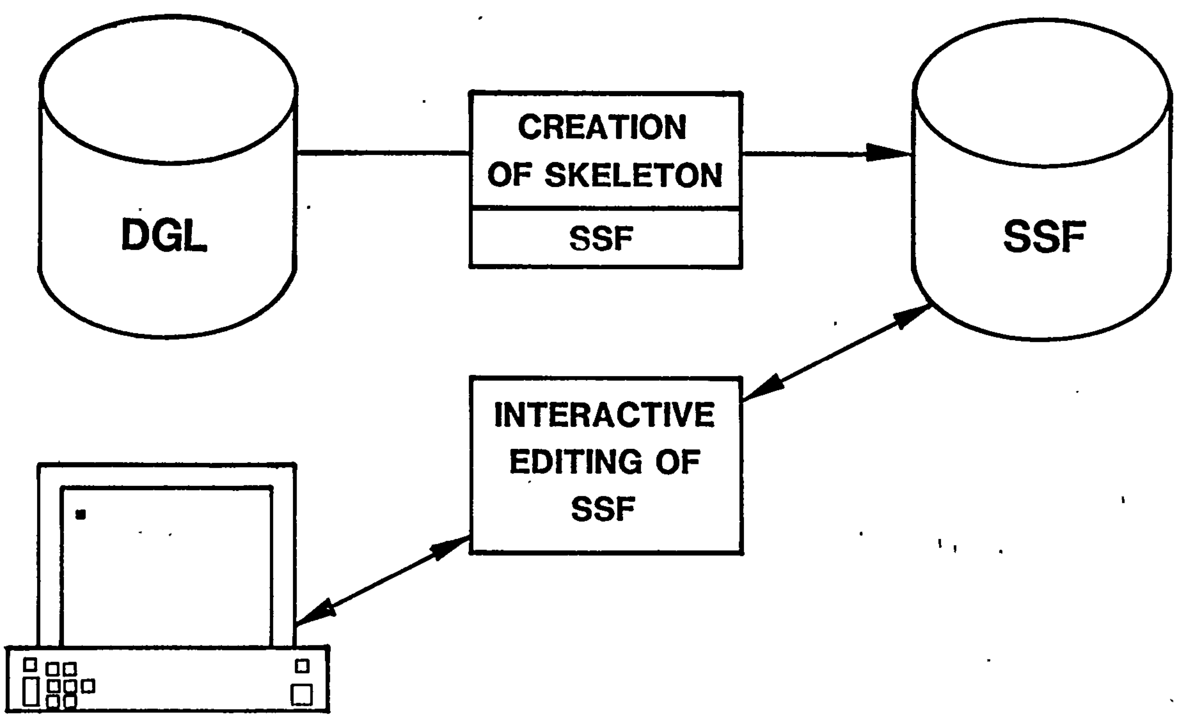


**Figure 1 -Creation of SSF**

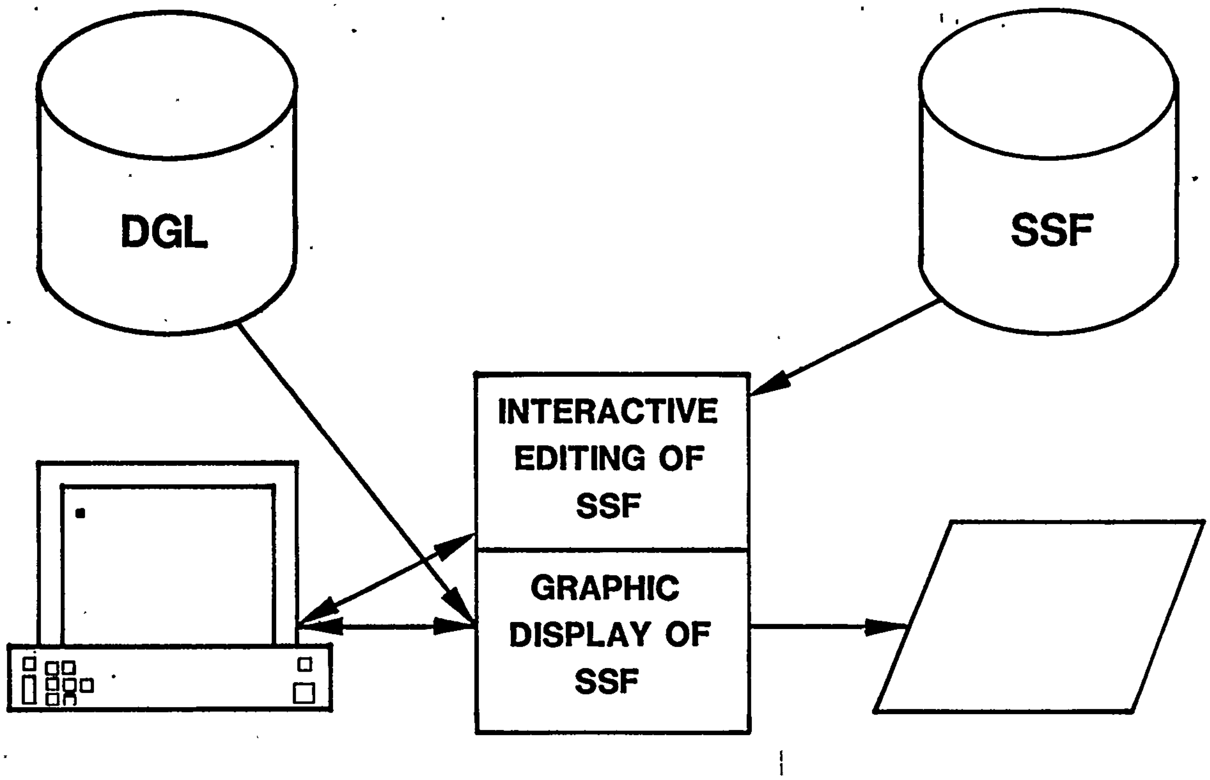


Figure 2 - Graphic Display of SSF

## SSF PROGRAM DESIGN CONSIDERATION

- INTERACTIVITY
- PORTABILITY
- RAPID FILE ACCESS
- EASY FILE EXPANSION
- PROTECTION OF DATA

## SSF UTILITY FUNCTIONS

- CREATION OF SKELETON FILE
- CREATION OF STANDARD SHAPES FILE
- PASSWORD CHANGES
- PACKING
- TRANSFER OF DATA BETWEEN COMPUTER SYSTEMS

## SSF EDITING FUNCTION/DEFINING STRUCTURES

- BOUNDING STRUCTURES AND SURFACES
- DEFINING SCANTLINGS OF SHAPES
- DEFINING PLATE THICKNESS OF PLATES
- DEFINING MATERIAL
- ORIENTATION
- DEFINING SURFACE INTERSECTION

## SSF EDITING FUNCTIONS/SEARCHING

- FINDS ANY MEMBER ON FILE
- FINDS NEXT PLATE. OR- PIECE
- FINDS SURFACE
- FINDS SPECIFIED SHAPE WITHIN SURFACE
- FINDS SPECIFIED PIECE WITHIN SURFACE
- FINDS SPECIFIED PLATE WITHIN SURFACE

ANY SURFACE, PLATE OR PIECE NOT FOUND RESULTS IN CREATION OF NEW ITEM

## SSF EDITING FUNCTION/DATA MOVEMENTS

- SETS ACTIVE BUFFER EQUAL TO SCANTLINGS FOR SURFACE, PLATE OR PIECE
- FILES SCANTLING RECORD, SURFACE PLATE OR PIECE
- DELETE SCANTLING RECORD FOR SURFACE PLATE OR PIECE

# REQUIREMENTS FOR FUTURE DATA BASE

- RAPID FILE ACCESS
- RECORD LENGTHS OF VARYING LENGTHS
- DIAL UP ACCESS
- *EASY ACCESS FOR ANY PROGRAM
- INTERACTIVlTY
- SHARING DATA BETWEEN COMPUTERS
- PORTABILITY
- DATA SAFETY
- DATA SECURITY

# INTERACTIVE COMPUTER SUPPORT FOR THE IMPROVEMENT OF PLANNING AND PRODUCTION CONTROL IN THE SHIPYARD ENVIRONMENT

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Captain Bihr holds a BS degree in mechanical engineering from Rensselaer Polytechnic Institute. He holds a MS degree in management service from the U.S. Naval Postgraduate School. He has undertaken postgraduate studies in communications engineering and in mathematics.

## ABSTRACT

Planning Research Corporation has been working with the U.S. Navy for the past 2½ years in providing a unique production management system for Navy Intermediate Maintenance Activities (IMAs). This system, successfully adapted from commercially proved techniques and underpinned by engineered labor performance standards, is in use at the Shore Intermediate Maintenance Activities (SIMA) Norfolk, Virginia and Mayport, Florida. Additionally, implementation of the system is underway on an incremental basis at SIMA, San Diego, California.

The engineered labor performance standards, developed as Engineered Time Values (E.T.V.), provide a means to accurately plan, schedule and progress work, to exercise production control on a real-time basis and to analyze factors affecting productivity in order to effect remedial action. A key feature of the Engineered Time Values (ETV) System is the Productivity Management Information Component (PMIC) which supports these functions through the use of interactive computer equipment.

In the planning function, ETV information resident in the PMIC is accessed by the assigned planner using a visual display terminal. The planner selects the operations required for the accomplishment of the work based on his job investigation. Using a conversational dialogue, the system provides a structured methodology guiding the planner through his normal mental process of planning the job while storing the planned data for further manipulation in a Jobs -in-Progress life cycle file. The ETV planning data is constructed around a permanent core of work steps based on a job hierarchial structure of key operations, tasks and components of work. Therefore, planning at all job levels is readily achieved. Once the job is planned and reviewed on the terminal, the planner *releases* the job to *a* printer for automatic printing of the job order, known in the E.T.V. System as a worksheet. The worksheet, in addition to listing the planned operations, displays a planned man-hour figure for the job which includes time for travel to the job site, job preparation and other allowances.

Scheduling and workload forecasting functions are also accomplished dynamically in the PMIC providing managers a real-time display of each shop's projected workload based on the planned man-hour figures generated for each job and the shop projected labor loading.

Work progressing and status information on each job are entered in the PMIC daily., Planned man-hours are automatically converted to earned man-hours as work on the job is completed. The resulting percentage of work completed on each job reflects actual job status in that the planned man-hour figure used is an aggregate of the engineered time values for the actual work steps involved in accomplishing the job,

As a result of the aforementioned PMIC applications, maintenance managers are provided an on-line production control capability by having at their fingertips actual remaining man-hour capacities in all shops for any given day of the current work week and for the upcoming work weeks. Therefore, the ability to optimize loading is available. This coupled with the additional PMIC functions of materials management, technical documentation support, status of labor availability, and plant/equipment capability provide a significant enhancement to the production control function. Dynamic, real-time computer assistance in the shipyard production management process can significantly improve the planning and control functions.

# BACKGROUND

SYSTEM FEATURES TO BE DESCRIBED BASED ON:

- ENGINEERED TIME VALUES SYSTEM FOR U.S. NAVY INTERMEDIATE MAINTENANCE ACTIVITIES
- REQUIREMENTS OF THE REPAIR ENVIRONMENT - NOT NEW CONSTRUCTION
  - RELATIVELY SHORT LEAD TIMES
  - FLEXIBILITY TO PLAN AND CONTROL WORK IN SUPPORT OF VOLATILE SHIP OPERATING SCHEDULES

HOWEVER:

- ADAPTABLE TO SHIPYARD REPAIR/OVERHAUL REQUIREMENTS
- APPLICABLE IN CONCEPT TO NEW CONSTRUCTION YARDS

# IMPROVEMENTS

# IN

# PLANNING

# PROVIDED BY

- STANDARDIZED PLANNING DATA
- STRUCTURED PLANNING PROCESS
- SIMULTANEOUS MATERIALS IDENTIFICATION

# STANDARD PLANNING DATA IN COMPUTER

## BASED ON

- INDUSTRIALLY ACCEPTED ENGINEERING STANDARDS

**AND**

- APPLICATION TO LOCAL SHOP WORK METHODS/PROCESSES

# STRUCTURED, PLANNING PROCESS

PLANNER ACCESSES STANDARD DATA AND PLANS

- UNIQUE/CUSTOMIZED JOB
- REPETITIVE JOB

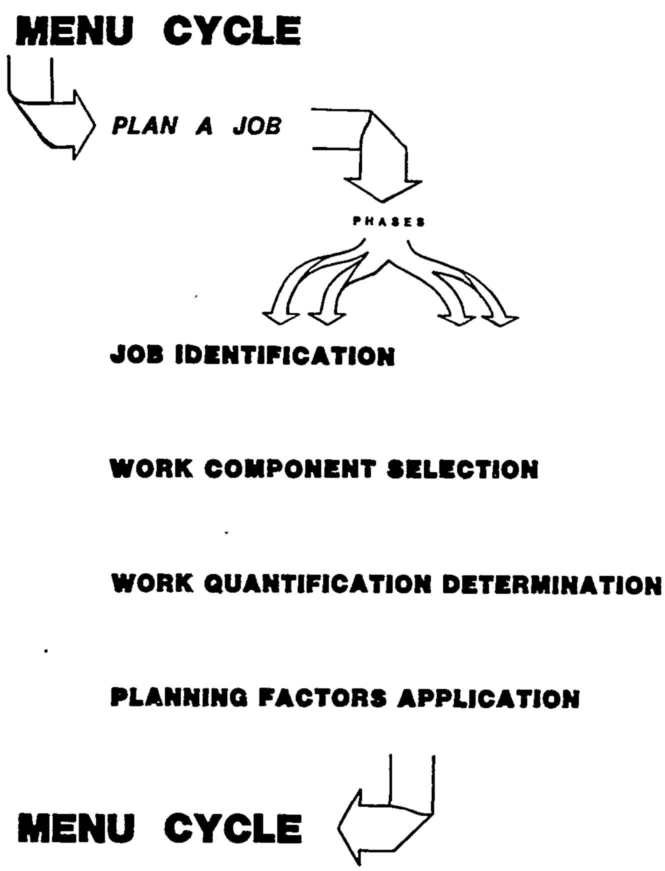
# FOR UNIQUE/CUSTOMIZED JOBS

- STANDARD DATA ORGANIZED AND SELECTED HIERARCHIALLY
  - KEY EVENT
    - JOB
      - KEY OPERATION
        - TASK
          - COMPONENT OF WORK
            - WORK OPERATION

- PLANNER SELECTS WORK ELEMENTS AT LEVEL DESIRED BY MENU SELECTION - COMPUTER ACCUMULATES TASK TIMES

- COMPUTER PROMPTS PLANNER THROUGH HIS NORMAL MENTAL PLANNING PROCESS

- COMPUTER ADDS ALLOWANCES TO GENERATE PLANNED TIME
  - JOB PREPARATION
  - SHOP/SHIP/SHOP TRAVEL
  - SHIPBOARD WORK ENVIRONMENT COMPLEXITY FACTOR
  - PERSONAL/REST/DELAY

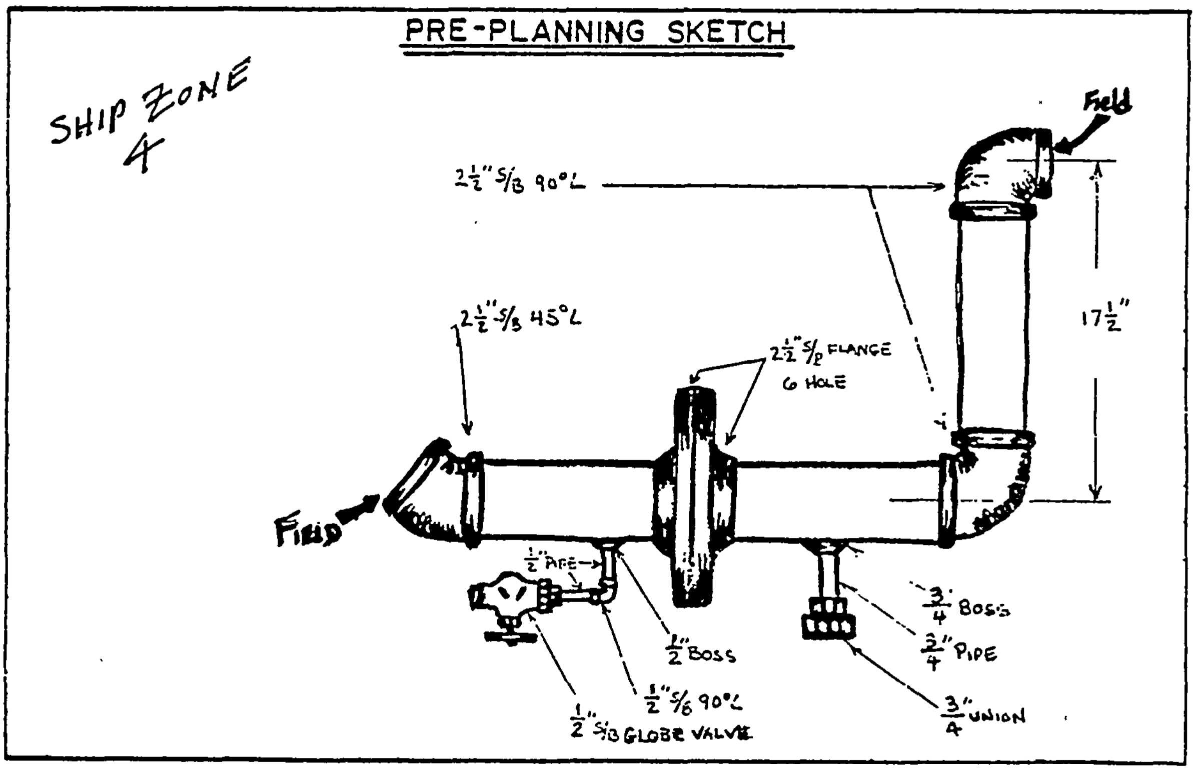


PLANNING / ESTIMATING MENU
SELECT ONE OF THE FOLLOWING :

1. MAINTAIN PLANNING FILE
* 2. PLAN A JOB
3. MAINTAIN SCHEDULING FILE
4. MAINTAIN PRE-PLANNED JOB FILE
5. REVIEW PRE-PLANNED JOB CATALOG
6. MAINTAIN JOBS-IN-PROGRESS FILE

SELECTION : 2

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)



**PLAN A JOB**

**SELECT ONE OF THE FOLLOWING TASKS :**

* 1. LWC-NEW JOB PLANNING
2. AWC-NEW JOB PLANNING
3. PRINT VERIFICATION LIST
4. ENTER CORRECTIONS
5. REARRANGE WORK OPERATIONS
6. PRINT WORKSHEET (RELEASE TO JIP)
7. REVIEW JOB PLANNING FILE

**SELECTIONS : 1**

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

**PLAN A JOB**

**NEW JOB PLANNING**

**DATE : 09/03/82 JULIAN : 2462**

UIC : 52702 W/C : ER04 JSN : 0582

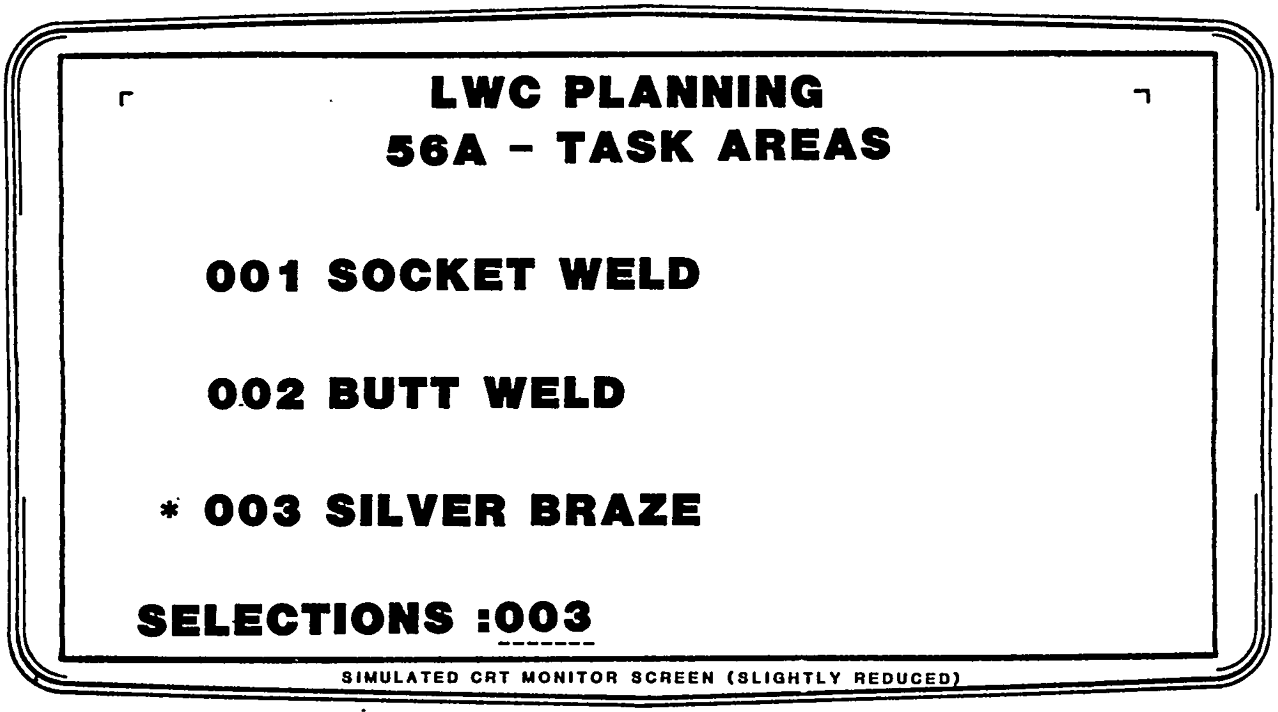
NAME : USS JOSEPHUS DANIELS

LWC : 56A

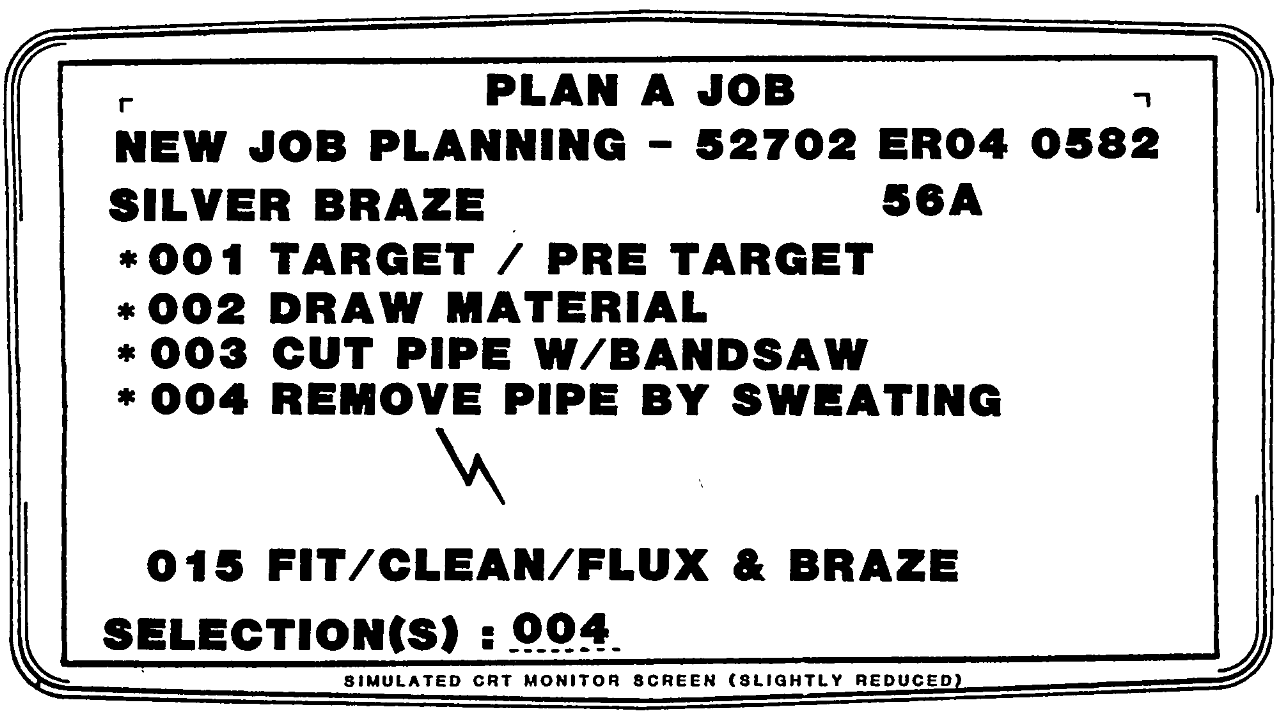
JOB DESC. DATA

DO YOU WISH TO PLAN THIS LWC :Y

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)




SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)




SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

**PLAN A JOB**

**NEW JOB PLANNING - 52702 ER04 0582**
**56A PIPE SHOP**
**003 SILVER BRAZE**
**004 REMOVE PIPE BY SWEATING**
**001 SWEAT UP TO 1 1/2" JOINT**
**PER JOINT**

**ARE YOU PLANNING THIS ITEM :N**

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

**PLAN A JOB**

**NEW JOB PLANNING - 52702 ER04 0582**
**56A PIPE SHOP**
**003 SILVER BRAZE**
**004 REMOVE PIPE BY SWEATING**
**002 SWEAT UP TO 3" JOINT**
**PER JOINT**

**ARE YOU PLANNING THIS ITEM :Y**

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

```
                 PLAN A JOB
NEW JOB PLANNING - 52702 ER04 0582
56A PIPE SHOP
  003 SILVER BRAZE
   004 REMOVE PIPE BY SWEATING
    002 SWEAT UP TO 3" JOINT
         PER JOINT
                           SHOP     SHIP
1. NO. OF MEN REQ'D.                 2
2.HOW MANY ITEMS :                   2
                          3.9230 E.T.V.

ANY CHANGES :N
```

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

```
                 PLAN A JOB
NEW JOB PLANNING - 52702 ER04 0582
                 56A-LWC       E.T.V.
                          SHOP       SHIP
        SUB TOTAL: 16.5540    10.5208
COMPLEXITY FACTOR: C           1.5781
       TOTAL E.T.V. 16.5540   12.0989
1.SHIP ZONE: 4
2.JOB PREP FACTOR-SHOP: A
                 -SHIP: C
3.NO.OF ROUND TRIPS PER DAY: 1
     PLANNED MANHRS : 20.5       19.1
     PLANNED MANDAYS : 04        03
```

SIMULATED CRT MONITOR SCREEN (SLIGHTLY REDUCED)

## FOR REPETITIVE JOBS

- SELECT PRE-PLANNED JOB ORDER
- ADD/DELETE WORK ELEMENTS AS NECESSARY
- SELECT ALLOWANCES AS IN CUSTOM JOB

## THEN PLANNER

VERIFIES PLANNING STEPS ON VIDEO TERMINAL

PRINTS JOB ORDER

SKA - LUC    S H I P / S H O P   W O R K S H E E T
USS JOSEPHUS DANIELS    SIMA NORFOLK
UIC# 52702  W/C# ER04  JSN# 0582    PAGE# 1    09/03/82 @ 114
SHIPBOARD COMPLEXITY FACTOR: C    PLNR# DON MC ANDREW
JOB DESC# REPLACE SECTION OF CHT SYSTEM    SHIP TRAVEL TIME ZONE# 4
IFT-SHIP = C  SHOP =
RT-SHIP = 1  SHOP =

| REF NO | W O R K   T O   B E   P E R F O R M E D | PLANNED SHIP M | QTY | C | PLANNED SHOP M | QTY | C |
|---|---|---|---|---|---|---|---|
| | | | E.T.V. | | | E.T.V. | |
| | SILVER BRAZE | | | | | | |
| 001 | VERIFY SYSTEM TAGOUT<br>CHECK TAGOUT (COSIGN)<br>PER JOB | * | 1<br>.5010 | | */////////// | | |
| 002 | SYSTEM DRAIN DOWN<br>CRACK UNION/FLANGE<br>PER UNION OR FL. | * | 3<br>.3576 | | */////////// | | |
| 003 | REMOVE PIPE BY SWEATING<br>SWEAT UP TO 3" JOINT<br>PER JOINT | * | 2<br>3.9230 | | */////////// | | |
| 004 | TARGET/PRE-TARGET (PER FL/BR)<br>UP TO 4" (FLANGE)<br>PER FLANGE OR BRACE | *////////////* | | | | 8<br>5.2980 | |
| 005 | DRAW MATERIALS<br>DRAW MATERIAL<br>PER #OF PARTS | *////////////* | | | | 15<br>.0923 | |
| 006 | CUT PIPE W/BANDSAW<br>CUT UP TO 1 1/2" PIPE<br>PER CUT | *////////////* | | | | 5<br>.1372 | |
| 007 | CUT UP TO 3" PIPE<br>PER CUT | *////////////* | | | | 6<br>.2050 | |
| 008 | FIT/CLEAN/FLUX/& BRAZE<br>FITUP(UP TO 1 1/2" JOINT)<br>PER JOINT | *////////////* | | | | 8<br>5.3608 | |
| 009 | FIT/CLEAN/FLUX/& BRAZE<br>FITUP (UP TO 3" JOINT)<br>PER JOINT | *////////////* | | | | 6<br>4.8750 | |
| 010 | FITUP (UP TO 3" JOINT)<br>PER JOINT | * | 2<br>5.7352 | | */////////// | | |

| START | STOP | | | SHIP | SHOP |
|---|---|---|---|---|---|
| | | ** | PLANNED - MANHOURS: | 19.1 | 20.5 |
| DATE: | | ** | | | |
| | | ** | DAYS: | 03 | 04 |
| TIME: | | ** | | | |
| | | ** | TOTAL - MANHOURS: | 39.6 | |

U N P L A N N E D   C O M P O N E N T S   O F   W O R K:

NOTE: 1. COLUMN "M" INDICATES NUMBER OF MEN IF MORE THAN 1 MAN FOR SHOP WORK OR 2 MEN FOR SHIP WORK.
2. USE COLUMN "C" TO CHECK-OFF WORK COMPLETED.
3. UNPLANNED COMPONENTS OF WORK - LIST MASTER WORKSHEET INDEX NUMBER OF THE COMPONENTS OF WORK COMPLETED BUT UNPLANNED. ALSO SHOW QUANTITY IF APP

# SYSTEMATIC MATERIALS IDENTIFICATION

MADE AT PLANNING TIME,

- PLANNER ENTERS MATERIAL REQUIREMENTS AGAINST JOB ORDER NUMBER
- INVENTORY AUTOMATICALLY ACCESSED FOR STATUS

IF ITEMS ON HAND:

INVENTORY ACCOUNT ADJUSTED

REQUIRED QUANTITY ADDED TO SUSPENSE ACCOUNT

PICKING TICKET PRINTED FOR PRE-STAGING

IF ITEMS NOT ON HAND:

JOB MATERIALS LIST (JML) PRINTED AT SUPPLY ORDER POINT FOR ACQUISITION ACTION

# IMPROVEMENTS

# IN

# PRODUCTION CONTROL

## PROVIDED BY

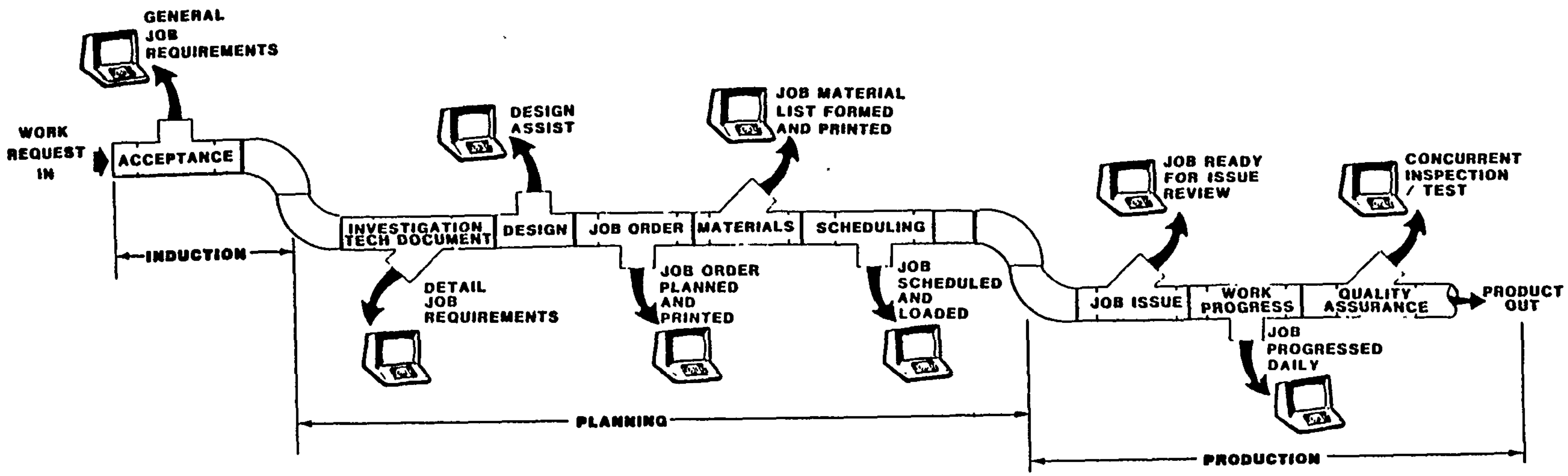
## REAL-TIME DISPLAYS/REPORTS

## SHOWING STATUS

## DURING ALL PHASES OF THE

## PRODUCTION CONTROL PROCESS

# THE FLOW OF PRODUCTION CONTROL



# DISPLAYS/REPORT STRUCTURE

- **DETAIL**
- **SUMMARY**
- EXCEPTION/ACTION
- JEOPARDY

# INFORMATION PRODUCTION DISPLAYS/REPORTS

DISPLAY - DYNAMIC SCREEN PRESENTATION

REPORT - HARD COPY

ETV-PMIC/062 STATISTICAL SUMMARY - BY REPAIR DIVISION/GROUP SIMA NORFOLK

| | UNASG | R1 | R2 | R3 | R4 | R5 | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|---|
| INDUCTED ----- | 0 | 11 | 15 | 4 | 3 | 1 | 4 | 38 |
| PLANNING ----- | | 96 | 334 | 41 | 25 | 52 | 5 | 553 |
| OVRDUE ---- | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SCHEDULING --- | | 94 | 225 | 40 | 4 | 26 | 3 | 392 |
| PLN HRS --- | | 2947 | 6585 | 1368 | 256 | 1064 | 92 | 12312 |
| PREP TO ISS -- | | 21 | 61 | 5 | 7 | 21 | 1 | 116 |
| PLN HRS - | | 779 | 1839 | 132 | 250 | 113 | 16 | 3129 |
| JOBS-IN-PROG - | | 131 | 269 | 55 | 31 | 110 | 0 | 596 |
| REM HRS - | | 3973 | 6520 | 1457 | 843 | 2231 | 0 | 15024 |
| TOTAL JOBS --- | 0 | 353 | 904 | 145 | 70 | 210 | 13 | 1695 |

09/08/82 17:26:18

Simulated CRT Monitor Screen - Actual Size /Characters Slightly Reduced

E N G I N E E R E D   T I M E   V A L U E S
JOB STATUS UIC SUMMARY BY SHIP
DATE: 09/08/82 & TIME: 1829

SIMA NORFOLK
RPT NO: ETV681JTA
PAGE 1

UIC: 20068 USS AINSWORTH    HULL: FF1090    AVAILABILITY: 0000000 - 0000000

| W/C | JSN | CSMP SUMMARY | T/A | LWC | R/HR | O/O | DATE | CODE | REASON | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| EB01 | 2374 | 1A BLR CAL YARWAY INDECATOR | I4AV | 41A | 9 | | 12AUG | | | SCH 27SEP2-01OCT2 |
| EB01 | 2375 | 1B BLR YARWAY INDECATOR CAL. | I4AV | 41A | 9 | | 12AUG | | | SCH 27SEP2-01OCT2 |
| EB01 | 2391 | OVHL VLV OPERATOR | E4RGNT | 38A | 1 | 90 | 31AUG | 19 | WAITG TECH DOC | RESCHEDULING |
| EB01 | 2414 | REPLACE BACK FILL VLV | SIMAV | 56A | | 100 | 07SEP | | | COMPLETED |
| EB01 | 2415 | REPLC OUTLET 1/2" GLB VLV | SIMAV | 56A | | 100 | 07SEP | | | COMPLETED |
| EB01 | 2423 | MFG NEW S/W LINE | SIMAV | 56A | 5 | | 08SEP | | | IN PROG-SC 12SEP2 |
| EB01 | 2529 | REPLACE BACK FILL VLV | SIMAV | 56A | 23 | 52 | 08SEP | | | IN PROG-SC 27AUG2 |
| EB01 | 2534 | REPLACE 1/2 INCH GLB VLV | SIMAV | 56A | | 100 | 07SEP | | | COMPLETED |
| EM01 | 1284 | BRIBBLE STUDS ON LP TURBIN | I4AV | 38A | 11 | 77 | 08SEP | | | IN PROG-SC 10SEP2 |
| EM01 | 1285 | LUBE SUMP INDICATOR REPAIR | I4AV | 56A | | 100 | 08SEP | | | COMPLETED |
| EM01 | 1300 | REPAIR L/O STRAINER BASKET | SIMAV | 17A | 18 | | 07SEP | | | I/S 13SEP2-17SEP2 |
| ER01 | 1256 | LOAD TEST AIRCRAFT TIE DOWNS | E/CSRP | 72A | 2 | | 03SEP | | | I/S 06SEP2-10SEP2 |
| ER01 | 1295 | REPAIR SEPTAR BOAT | E/CSRP | 64A | 199 | 100 | 08SEP | | | IN PROG-SC 13AUG2 |
| EXJC | R029 | TSET INSPECT RELIEF VLV | I4AV | 96A | 3 | | 17AUG | R6I | CANX BY S/F | PE REC REJ |
| EXSA | 1221 | NONE | SIMAV | 11A | | | 02AUG | R6I | MDC ERR | TYCOM REP REC REJ |
| EXSA | N760 | DAC INSTALL SHIPALT FF-1052-52 | SIMAV | 56A | 56 | | 07SEP | | | I/S 13SEP2-17SEP2 |
| SX01 | 0366 | MFG PLAQUE BACKS | SIMAV | 64A | 29 | | 08SEP | | | IN PROG-SC 26AUG2 |
| WD01 | 1155 | MFG 10 SECUR BRACKETS | I4AV | 11A | 15 | | 27AUG | | | I/S 06SEP2-10SEP2 |
| WD01 | 1276 | WEIGHT TEST BOAT DAVIT | E4RGNT | 72A | 31 | 31 | 02SEP | | | IN PROG-SC 13AUG2 |
| WD01 | 1277 | MFG PREVENTER SPAN LINE | E4RGNT | 72A | 11 | 47 | 31AUG | | | IN PROG-SC 20AUG2 |
| WD01 | 1278 | WEIGHT TEST BOAT DAVIT | E4RGNT | 72A | 30 | 33 | 13AUG | | | IN PROG-SC 13AUG2 |
| WD01 | 1279 | MFG DAVIT HEAD PREVENTER | E4RGNT | 72A | 12 | 40 | 31AUG | | | IN PROG-SC 20AUG2 |
| WD01 | 1280 | MFGDAVIT HEAD PREVENTER | E4RGNT | 72A | 4 | 81 | 31AUG | | | IN PROG-SC 20AUG2 |

# IMPROVEMENTS IN PRODUCTION CONTROL

FURTHER PROVIDED BY

- ABILITY TO PROGRESS EACH JOB ACCURATELY
  - EARNED MAN-HOURS = % COMPLETE
- ABILITY TO MONITOR AND CONTROL WORKLOAD
  - BY SHOP
  - REMAINING LOAD VS UNUSED CAPACITY
  - OPTIMIZE RESOURCES
- ABILITY TO MONITOR PLANT CAPABILITY STATUS
  - END RUN CHOKE POINTS
- QUALITY ASSURANCE AUDIT TRAIL

# IN SUMMARY

INTERACTIVE ADP EQUIPMENT OFFERS

- RESPONSIVE MANAGEMENT OF PLANNING/PRODUCTION CONTROL INFORMATION
- PROCESS DISCIPLINE
- READILY ACCESSIBLE HISTORY
- TRAINING CAPABILITIES
- PAPERWORK REDUCTION
- ENTRY TIME DATA VALIDATION/VERIFICATION
- GRAPHICS/NETWORKING CAPABILITY

# INTERACTIVE SYSTEM
# DEVELOPMENT RULES

- MODULARIZE, MODULARIZE AND MODULARIZE
- BUILD-IN TRANSPORTABILITY
- USE STRUCTURED PROGRAMMING TECHNIQUES - FROM THE BOTTOM - BUBBLE UP, NOT TRICKLE DOWN
- PROVIDE FREQUENT USER INTERCHANGE
  1. DESIGN AND FIELD CHECK
  2. DEVELOP AND FIELD CHECK
  3. TEST AND FIELD CHECK
  4. PLACE IN OPERATION AND FIELD CHECK
  5. DE-BUG AND FIELD CHECK
  6. GO TO 1.
- AUTOMATE INTERFACES - ONE TIME DATA ENTRY
- USE VIDEO DISPLAYS - ESCHEW REPORTS
- PROVIDE INFORMATION - NOT DATA
- EMPHASIZE MBE - USER PROVIDED CRITERIA
- PROVIDE JOB STATUS CONTINUOUSLY

0009

# RAPID DEVELOPMENT OF PRODUCTION SCHEDULES WITH STANDARD PLANNING MODULES

Stephen M. Knapp
Senior Planning Associate
SPAR Associates Incorporated
Annapolis, Maryland

Mr. Knapp is currently developing a formal shipyard planning document which will be available to client yards using the Standard Planning Module discipline. Recent achievements include the development of a planning network for the Saint John Shipbuilding and Dry Dock Company, Saint John, New Brunswick, Canada, for an AKER designed, semi-submersible drill rig, and directing the planning of the "Debbie D", an imaginary drill rig work boat used by SPAR for client training. Another ongoing task is the development of a 7000.2 compatible material cost performance report as a feature of SPAR's MAT-PAC material control system.

Mr. Knapp has been active in the Planning and Scheduling aspects of the shipbuilding industry since 1977, and has been an annual speaker at REAPS sysmposiums since 1979. He holds a bachelors degree and has completed post-graduate work in computer science.

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Stephen M. Knapp
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## PREFACE

Following the premise of engineering standards, Standard planning Modules represent production work package arrangements which are predefined to simplify the creation of planning networks at the central planning level, The approach centers around the notion that a vast majority of production activities can be established without the aid of available, detailed engineering. The creation of workpackages under this approach is dependent solely upon historical production performance, adaptation of work from previous vessels of the same class, specific details provided by the vessel's specification, and general arrangement engineering drawings. Final production schedules, at the workpackage level, become a derivative of the planning schedule as detailed information becomes available from engineering, material procurement, and other sources,

## TRADITIONAL PLANNING'

The nature of planning a ship's construction has historically dictated that most, if not all, of the ship's details be known. Working from production drawings, Planning generates the varied labor workpackages necessary to support the fabrication and installation of steel and systems, Since Planning waits for such detail to be available, the timing of the production schedule development tends to occur immediately before those schedules are needed by the yard. In fact, a common complaint of many shipyards is that the production schedules are often published after preliminary construction has begun, normally in the form of steel cutting and substructure assemblies, This tardiness further re-

stricts the ability of Planning to conduct such analyses as man-power availabilities, facility readiness, and cost-to-schedule trade-offs.

Such studies are necessary to give the shipyard any advanced notice of production problems, Other analyses which are of equal benefit are those which can improve the producibility of the vessel by planning for pre-outfitting, modularization, and family manufacturing, The ability to foresee production problems and to plan for alternative construction techniques are other benefits which are lost due to the timing of traditional planning,

Another observation is that, under this information-constraint approach, Planning in incapable of assisting any of the departments which lead the vessel's construction. Therefore, engineering tends to dictate to production the release, and hence, the building, schedule for ship's construcion, Material procurement, often faced with the complication of long-lead time item purchasing, must use either the drawing release schedule, historical purchasing trends, or purchase the troublesome items early and hope for the best.

Given today's economic pressures on the shipyards' order books, Planning must derive a mechanism to permit a more rapid development of the production schedules, Even if the preliminary schedules are to be classified as estimates, they Offer the shipyard the opportunity to inspect a potential plan well in advance of construction, It is better to criticize a plan dubbed as "crude" than to have no plan to inspect at all.

## COMPARISON TO ENGINEERING STANDARDS

The concept of engineering standards, as is known throughout the industry, is to affix production labor and material cost estimates to production activities, The term "estimate" is weak in that the discipline of engineering demands a more formal assignment of production requirements to the elements of the project. Working from recognized standards, engineering is able to derive the accepted time durations and costs associated with *any* detailed *as*-pect of the vessel.

This approach forms the foundation for planning standards, While the shipbuilding industry lacks any documented data on fabrication and installation of production requirements, each yard can develop a sufficient standard-base from which adequate planning estimates can be derived, Such standards would specify:

IREAPS standard Planning Modules

a) Workpackage content

b) Trade classes required

c) Assigned workpackage budget in manhours

d) 'Trade class manhours or distribution percentage'

e) Optimal duration in work days or weeks

f) Cost account

While the method of assigning standard data to a single package may seem interesting, the approach can be taken further by the definition of standard modules, These Standard Planning Modules, or SPMs, permit the development of standard relationships between the already defined standard workpackages, Thus, the inclusion of a SPM into the plan for the vessel will automatically define all of the associated work elements needed to complete the task, An example of one SPM would be a set of workpackages to procure, engineer, fabricate, assemble, erect, and weld a steel unit,

Although SPMs constitute a building block of planning standards, there is no limit to the number of such SPMs which can be defined. If a documented SPM proves inadequate, or if an alternative construction approach is desirable, a "clone" of the SPM can be easily defined and used.

A Standard Planning Module is given the following attributes:

a) It should contain all of -the necessary production and non-production workpackages so as to fully accomplish the desired task.

b) It should be presented in a form conducive to the normal planning methods used by the shipyard, That is, if the yard's planning staff uses a networking system, the SPM should be presented as a subnetwork.

c) For networks, it must contain all of the necessary "dummy" links to insure proper package-to-package relationships.

d) All packages within the SPM must be defined under the rules for a standard workpackage,

e) **Workpackages cannot. be** assigned fixed dates,

f) Relationships **of packages must be** in a variable **format** so as to permit their adaptation to any portion **of the** plan. **That** is, **such numbers as zones, work** centers, **and** hull numbers should **be undefined** until actually incorporated into the plan,

Experience with the use **of SPMs ha**s shown that two basic types **of SPMs are** required **for the** shipyard, **The are** classified as "standard" **and** "ship's specificU SPMs, **The differences** lie in the fact. that. certain classes **of** vessels will require **certain work pack age** configurations which may **never be presented** in a shipyard's set of standards. **An example** of a ship's specific SPM would **be the** command and **control** hardware installation for a combatant, **The** establishment of **such SPMs** would incur a one-time-only cost, **and would** be used **for** the preliminary plan in **the same manner as the normal, standard SPMs.**

**With adequate** shipyard planning procedures to facilitate **the use of such standards,** Planning should be capable of defining **most of the** vessels **workpackage** requirements working from the yard's usual **chart-of-accounts,** general arrangement design drawings, and the specification **for the** vessel.

Documentation of the **SPMs** is vital to insure that all **planners are** using the correct versions of each SPM. A master **book, or** some adequately maintained **computer** file **must- be used** to record **each SPM, along** with supporting data to describe **the** standard workpackages contained therein,

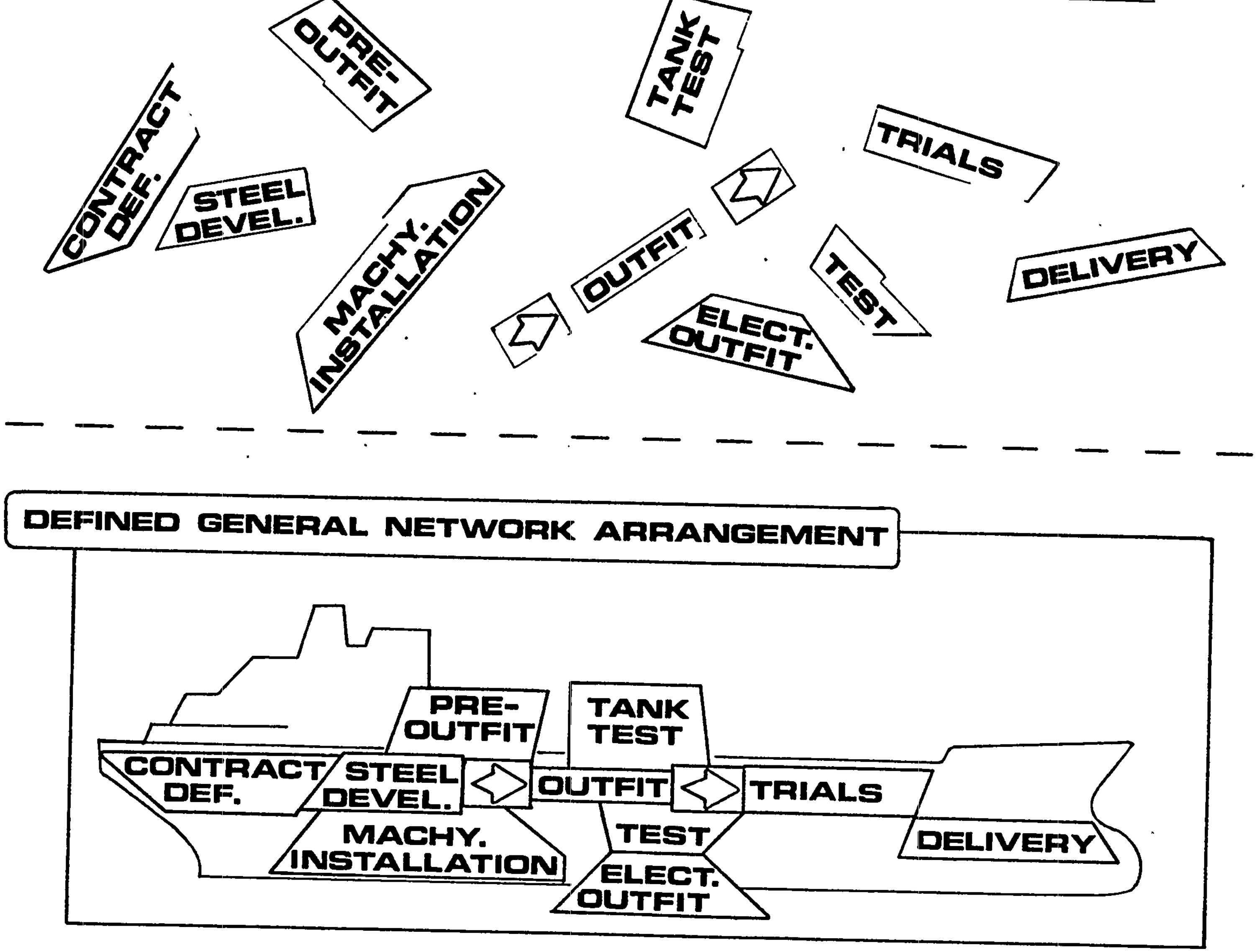
## ADAPTATION OF STANDARD PLANNING MODULES

**The process of** creating a ship's plan involves the coordination of **work** activities covering the entire realm of ship construct.-ion. Visualized as a jig-saw **puzzle** (Figure 1), **the** objective **of** Planning is to combine all of these required **elements** into **a cohesive plan,** and if all **of the parts are present, then the resultant.** plan will be completely defined, With the introduction **of** Standard Planning Modules, **the process** of combining the **required** work becomes simplified, since **the** definition **of the SPM** insures planning completeness at a finite level.

**Accuracy of the plan** is defined as the proper relationship of **workpackages** to one another, Working **from a** realistic gameplan of plan generation, **the** incorporation **of the SPMs** insures that. **work** relationships **below the master plan** level retain their pro-

# PRODUCTION SCHEDULE DEVELOPMENT

FIGURE #1



per relationships,

With the SPM providing a firm foundation for the plan, the next objective is to provide a proper mechanism for the gathering of the SPMs into a complete plan. Since the underlying theme of standardized planning is to advance the timetable of the planning process, Planning must rely heavily on the definition of the standards since production drawings will probably not be available, The collection process centers around a plan framework which represents the major milestones or prevalent work paths through the construction process, If viewed as a network, this framework is a skeleton network comprised solely of dummy (zero duration) activities (see Figure 2). The framework identifies major steel blocks, outfitting zones, and recognized systems test criteria. Where required, each of these categories can be further subdivided to improve clarity for the planners who will subsequently “fill” the skeleton with SPMs.

Simply stated, the loading of SPMs to the plan merely requires that the Planner select a single SPM which best describes the work elements for any piece of the vessel. The specification for the vessel should provide ample descriptions of the required systems (cost accounts) that will be required. Marking with the shipyard's chart-of-accounts and the specification, the Planner choses the most likely SPM to accommodate that system in any given zone (note #1). Repeating this process through all systems : selecting or discarding accounts based on the experience of the planner, indications from the specification, and interpretation of the design drawings, the Planner creates the preliminary plan. Figure 3 shows a simple SPM used to create all of the steel workpackages for a single steel unit, When used repetitively for all steel units defined or assumed for the ship, all of the steel related activities will be defined in the plan. The only remaining step for steel is to apply linking activities, which may be another SPM, so as to realize a steel erection plan,

A SPM can be simple, as in the case of Figure 3, or a compound SPM which gives the Planner additional, optional selections from which to choose for loading to the preliminary plan. Figure 4 illustrates a compound SPM. Note that not all of the activities need be chosen, and that this single SPM actually presents numerous subnetwork paths, any of which may be used. The Planner need merely insure that an unbroken path is ultimately selected when using this SPM.

Note #1 : SPAR’s planning discipline supports the zone approach, in that workpackages are defined as cost account by zone.

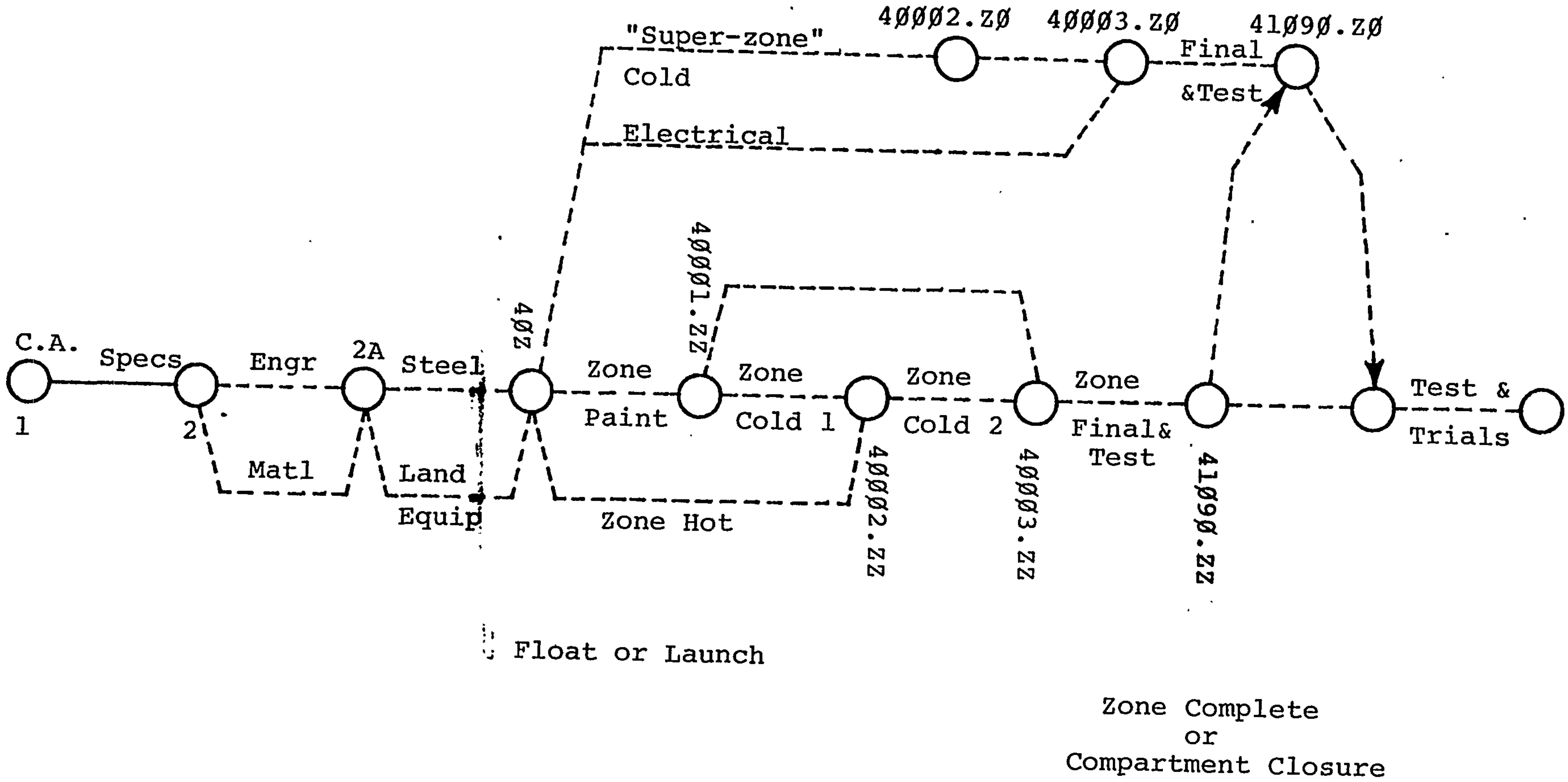
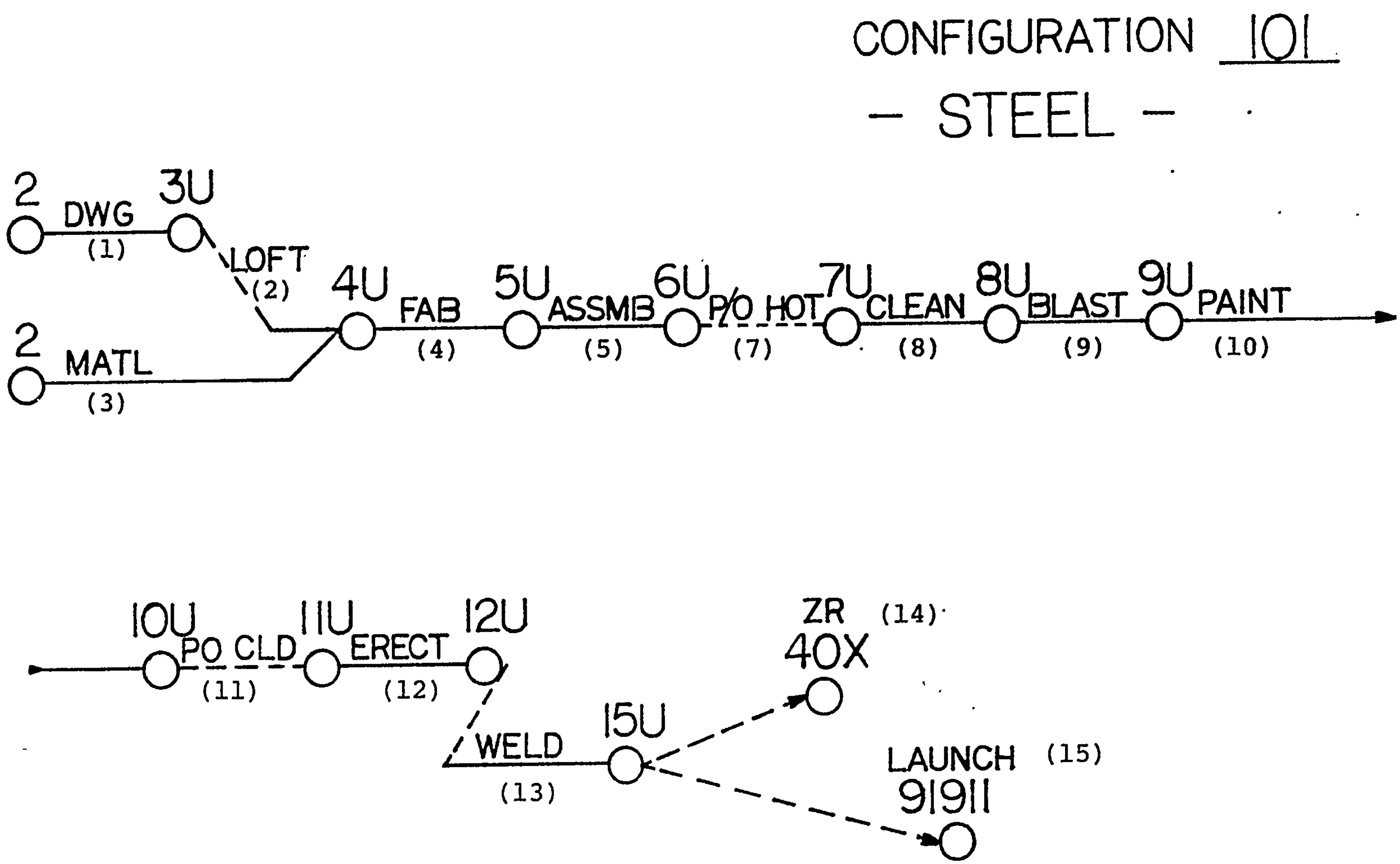



Figure 2: SPM Network Skeleton

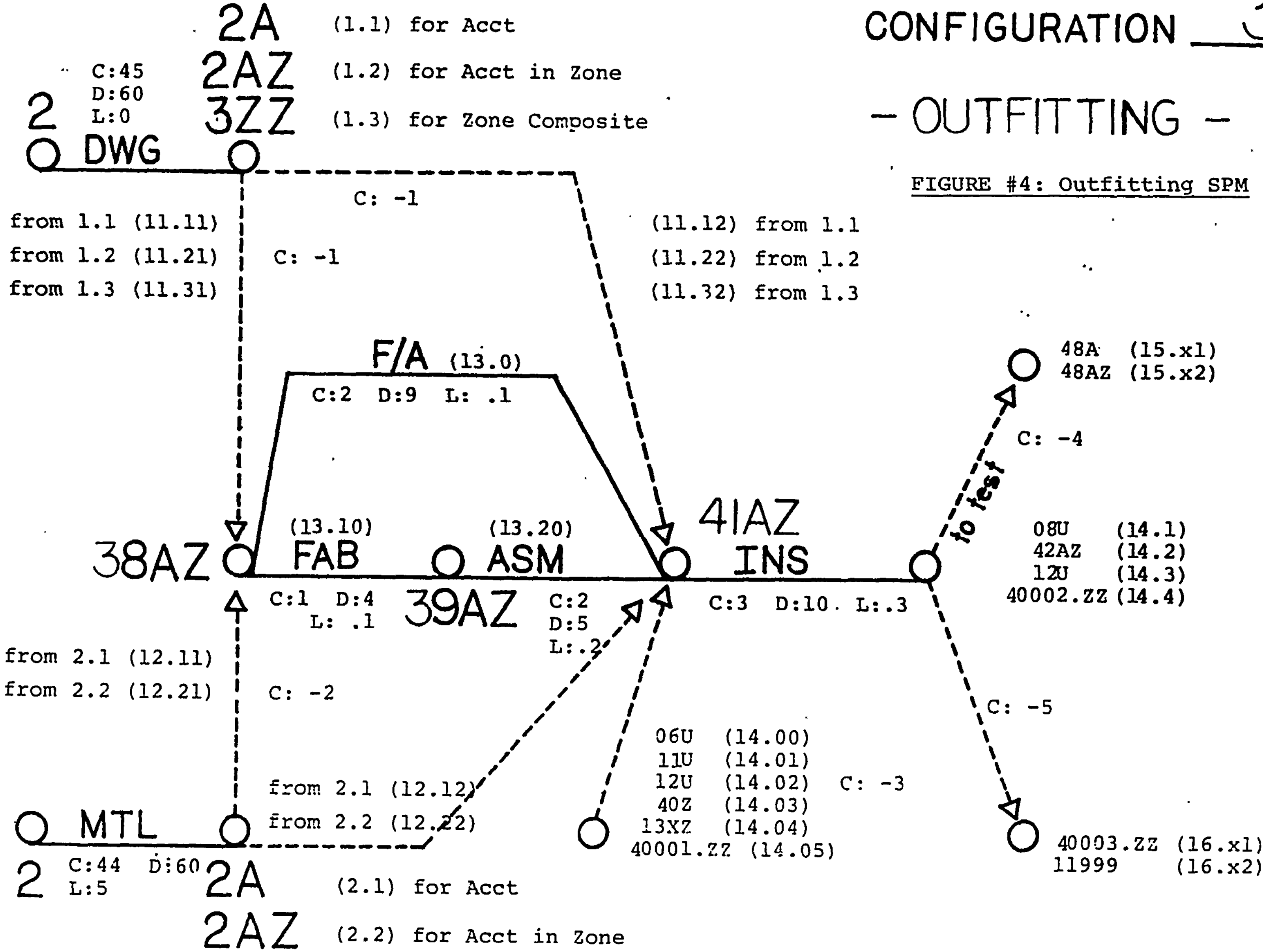
FIGURE #3: Steel SPM



CONFIGURATION 3

- OUTFITTING -

FIGURE #4: Outfitting SPM



Equipment is accommodated in the same fashion, with the **Planner** using **SPMs** specifically designed for the installation of major machinery, In this case, **the SPM** contains activities for the fabrication and installation of equipment. foundations, **and for** the procurement, assembly, and installation **of the** machinery itself. Sophisticated equipment SPMs can contain dummy linking activities for the constraint **of** closing steel units, and can be adapted for pre-outfit equipment installation or modules requiring multiple systems, Figure 5 depicts one Standard Planning Module for machinery installation,

Procedures must be in place within the Planning organization to insure that SPM selections are documented to show which **systems have been planned,** the degree of steel completed, pre-outfit and modules defined, and **whatever** variations in **SPM** selection was required, One recommendation **for** this approach would be the development **of a** ship's Plan **Book, The** form of the Plan **Book (not** defined in this paper) constitutes a working document. **through** which Planning **can** communicate the progress, problems, and assumptions **of** the plan to all concerned shipyard departments. Such documentation is important **because** the advanced, preliminary plan does not constitute a production schedule, due primarily to the lack **of** production drawings. The Plan **Book** will provide for a formal guide **for** the transformation of the preliminary plan, **and** its resultant schedule, into the final production schedule,

## THE PRELIMINARY SCHEDULE

**The** result of collecting SPMs is a conglomeration of standard workpackages. If **the** shipyard is using a networking system, these workpackages are tied together via the relationships of **that** computer system. The networking system need only be executed to derive the dates **for each of** the workpackages. If t-he shipyard is not using networks, each workpackage must. be scheduled either manually, or **through** some form of static scheduling system **(note #2).**

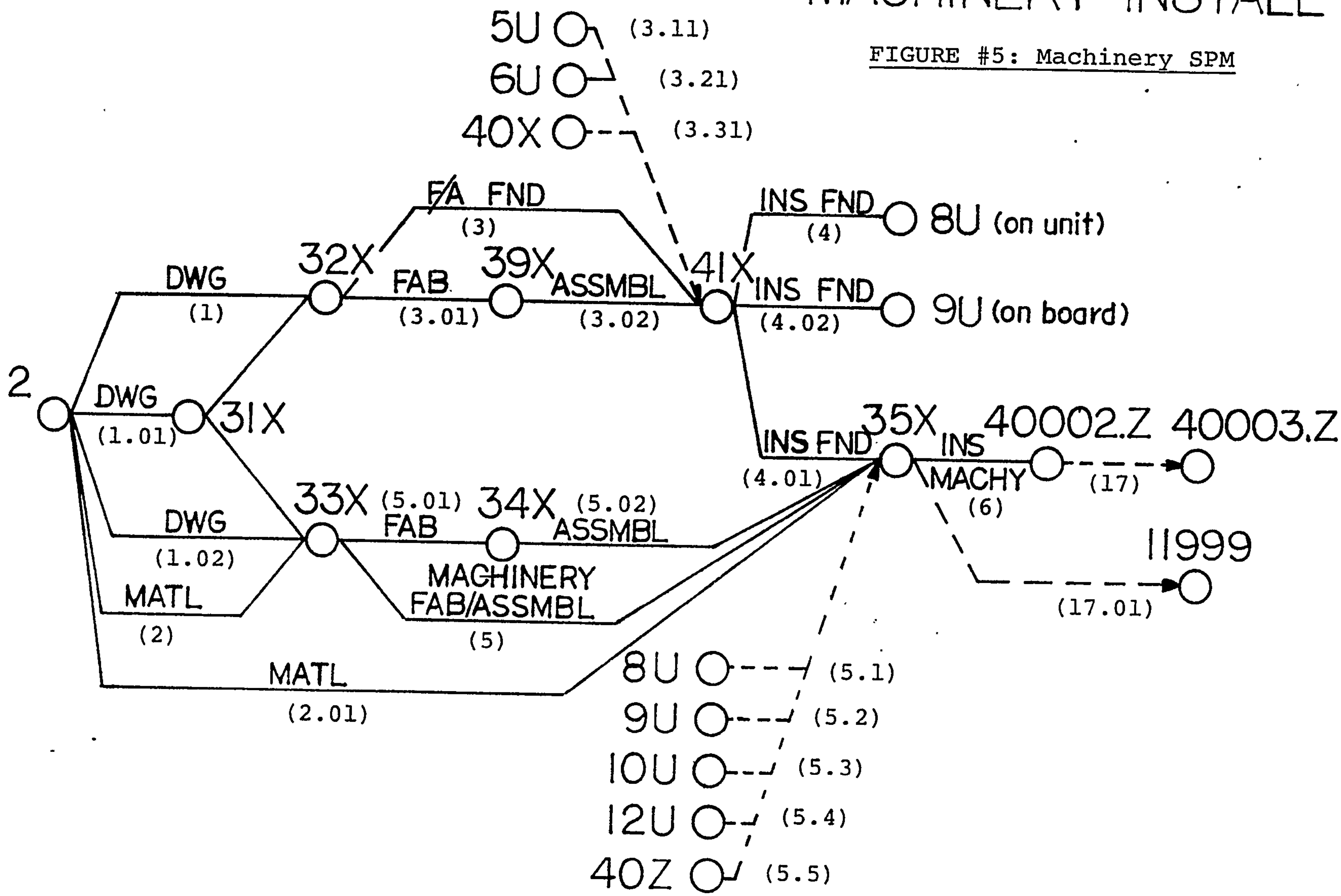
--------------------------

**Note #2: No known** computer system can schedule workpackages on a static basis unless dates are manually input and subsequent schedules **adjusted** based **on** resource contraints or **other** criteria,

CONFIGURATION II

— MACHINERY INSTALL —

FIGURE #5: Machinery SPM



Regardless of scheduling method, the **resultxnt** schedule could **not.** possibly **be** used for production, This is because:

a) Standard steel durations vary depending **upon** unit complexity,

b) **Special systems may not be** identified from available **data sources,**

c) Specific production strategies may not be obvious from design drawings,

**d)** Budget and duration **estimates may not be** realistic,

e) Trade class requirements may not. be camp-letely visible, and

f) Any number of other obstructions could cloud the plan,

**But,** the initial objective **of the** standardized approach is to derive a plan which can be criticized, With proper use, over 80% of the production workpackages will be defined. By understanding **the specific** functions **of** the vessel being planned, **an** additional 10% **of the** required workpackages can be added as “discrete” pack-**ages,** which can come from the pool of standard workpackages, It is understood **that the** remaining 10% of the workpackages will be included **as more-and-more** details **become** available to **the** Plan-ning **staff,** **These** will be added to either **the** preliminary plan **as** detected, **or** to **the** final production plan **after the transform**-ation **has occurred.**

**This** preliminary plan, and its **schedule, offer the** shipyard **numerous advantages, even** considering its generalizations, **Of** principle interest is the potential **for** conducting initial asses-**sments of** construction timing, manpower loading, facilities availability, and milestone definition,

**From the** workpackages, budget estimates can be summarized to cost account levels and compared to contract, or bid, **estimates to** gain some indication as to the level of accuracy of the compon-**ents of the bid,** With Production involved in **the** evaluation **of** planning standards as applied to **the** vessel in question, Planning can determine which cost accounts will possibly offer the most problems in terms of actual to **estimated costs.**

Manpower loading reports (note #3) and the network's critical path report can give indications as to which aspects of the vessel's production will require more extensive cost/schedule controls.

The preliminary schedule's milestone report can be compared to contractural milestones to determine the accuracy of the plan's "fit," Large deviations in milestone dates can pin-point those areas where more investigation into the relative accuracy of the standards is needed.

The preceeding analyses can be repeated as often as required until the preliminary plan assumes a form acceptable to Planning, Information drawn from this advanced planning allows the shipyard to extract vital data, such as:

a) What material/equipment is demonstrating a potential purchasing problem,

b) What the general fireing order of engineering drawing release will be required,

c) What shops in the yard are suspect to have manning problems, and

d) Which areas of the production approach should be given special attention for alternative methods,

## TRANSFORMATION TO PRODUCTION SCHEDULES

Since the preliminary plan is comprised of any number of gross estimates at. the workpackage level, Planning must transform that plan into a viable production plan and schedule, The changes required can be itemized.

Note #3: We assume that most networking systems will have some form of resource loading or manpower loading capabilities,

a) DELETE packages or entire cost accounts that were assumed for the vessel but are not actually required.

b) ADD packages or cost accounts that were omitted due to insufficient information. These will mostly be those seldom used accounts or new accounts not previously in existance at the yard.

c) ADJUST packages in terms of their duration or budget or trade class assignments as supported by the production drawings,

Since SPMs were used in the development of workpackage groups, the deletion of those packages requires that the SPM loading process merely be reversed, This can be accomplished by the deleting of each individual workpackage or dummy link, or by some automated process whereby the system can recognize the SPM load and automatically remove the packages. In a similar fashion, the computer system should be capable of deleting workpackages under a given cost account,

The addition of workpackages under new or existing cost accounts involves the continued use of the SPM concept, inserting the required workpackages as would have been done during initial plan development had that work requirement been known at that time.

The adjustment of existing workpackages will constitute the majority of the transformation process, This comes about When Planning gets the necessary, additional information from the production drawings and is better able to derive realistic budget and duration estimates. The role of the SPM has no influence in this case,

Of interest to note is that this entire transformation process requires very little time to adjust and enhance the plan. Since most of the required workpackages will exist in the plan, it becomes a matter of reviewing each package, or groups of packages as generated by a SPM, and modifying the plan based on the improved availability of information. Ongoing to this transformation of the preliminary *plan* to a production, the repeated evaluation of interim schedules can continually upgrade the decision making process of the shipyard regarding production techniques and alternatives. Engineering and material procurement cycles can be evaluated on a continual basis and markedly improve the responses of these department= to the dynamic posture of the vessel.

## IMPROVED PLANNING RESPONSE

**The** question of timing **began** with **the** introduction **to Standard** Planning Modules, with the **general statement** of increased **Planning response** time via planning **standards,** As mentioned, **the** necessity for waiting **for** production drawings from engineering is eliminated in **favor of standards,** all **of** which would be tailored for the individual shipyard.

Figure **6 presents** the sample computations, with assumptions, that indicates **the** possible timing savings **of the SPM approach. The** figures do not **represent any actual** ship, but **are** established for **the point of** comparison only. **What** is not immediately apparent is **the advanced** planning development schedule which **falls out of the SPM** techniques, **that** being the availability **of** planning schedules **much** earlier in the ship construction cycle. It is theoritically possible to begin this planning process at the point **of Request-for-Quote, but it would more naturally occur** in an overlapping time frame with **the** contract award. In situations where all **of** the production engineering must **be** done, that is, no **such** engineering is available **at contract award, there** is **no reason why** all **of** the required central planning **cannot** be **completed** prior to any start of construction,

Standard Planning Modules, Example of Time Savings
(Figure 6)

| TASK DESCRIPTION | Mandays w/o SPMs | Mandays w/SPMs | Remarks |
|---|---|---|---|
| Review Spec | 5 | 5 | Same for both |
| Review Design Dwgs | 2 | 2 | |
| Zone Ship | 3 | 3 | |
| Unit Ship | 3 | 3 | |
| Review SPMs | 0 | 2 | Not req'd for traditional planning |
| Write 80% of workpackages | 60 | 0 | SPMs provide standard workpackages |
| Write 10% of workpackages | 10 | 5 | SPMs reduce time to develop discrete pkgs |
| Write 10% of workpackages | 10 | 10 | Same for special pkgs |
| Gather SPMs | 0 | 30 | |
| Evaluate Schedules | 5 | 5 | |
| "Transformation" | 0 | 10 | See text for discussion |
| Final Review and publication | 5 | 5 | |
| Totals | 103 | 80 | For a 22.3% time span reduction |

## A SYNOPSIS OF STANDARDS

The adaptation of standards to the shipyard planning environment is by no means a simple task, The best planning experience must be coupled with a active involvement of the production, material, and engineering departments to derive standards by which planning can make realistic attempts of planning the ship without detailed production drawings, Also, the estimating department must become a close ally to planning since the SPM concept through planning can enhance the efforts of the estimators.

Furthermore, the use of such standards requires a re-evaluation of the planning policies and procedures, Experpience has shown that the traditional approach to planning, generally preferred by the "old salt" planner, is usually a detriment to the successful implementation of SPMs. Shipyards which have or are currently adapting this concept are realizing the necessity of establishing some form of planning discipline, coupled with a semiformal (of even formal) set of written guidelines to direct the development and use of standard workpackages and the SPMs. Training and a more strict approach to planning management also contribute to the successful use of planning standards,

## APPLICATIONS

SPAR Associates began a formal development of the SPM concept in 198l while developing workpackage plans for a 37,000 DWT tanker, Experience from that vessel lead to the development of a ship's “Plan Book” which attempted, somewhat. trivially, to define the discipline by which SPMs could be adapted, and to present a formal document for planning,

In the Winter of 1981/1982, SPAR employed the Plan Book approach and its standards to a semi-submersible drill rig. The approach developed approximately 12,000 of the eventual 13,500 activity network, which represented over 5,000 production workorders. further refinement of the standards insued *as* insight was gained into the problems of a “large” network.

From experience on this drill rig, SPAR formalized its SPM control document and planned a theoritical work boat, the "DEBBIE D," so as to experiment with such items as "super-zone" definition, block to grand-block relationships, more visible preoutfit reporting, and *a* re-definition of certain network methodologies such as node numbering and pictorial presentation,

The development of a discipline for incorporating planning standards is on-going, and is gaining momentum as SPAR continues to develop plans for client shipyards;,

# STANDARDS FOR PRODUCTION PLANNING AND CONTROL IN SHIPYARD SHOPS

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ABSTRACT

This paper addresses the problem of establishing meaningful work order labor budgets for use in a shipyard pipe fabrication shop. Two methods are described for developing planning or scheduling standards. The first builds upon an existing base of detailed fabrication labor standards, which may be engineered standards or measured standards. The second uses sampling and statistical analysis to develop the planning or scheduling standards in situations where there are no existing labor standards. The first approach was applied in a seven month pilot project sponsored by the Maritime Administration through the Ship Producibility Research Program. The procedures and results of this pilot project are described. The primary result was a fifty percent increase in the perceived capacity of the shop, with no additional investment in .equipment or labor.


## 1.0 INTRODUCTION

AS early as 1881, Frederick W. Taylor proposed that the work of each employee be planned out by the management in advance, with the worker receiving complete task instructions as well as the means with which to complete the task. Taylor's system fixed a standard time to each job following time studies by "experts" based upon the work possibilities of a "first-rate man." This worker was instructed in the proper work method and able to do the work regularly. Thus began the systematic study of motion and time. Taylor's guiding principles of planning the work, designing the proper work method, and measuring the time to complete the work are still valid today.

In the U.S. shipbuilding industry today, the development of labor standards is not universal, although it is reasonably wide spread. The two most common applications of labor standards are for methods analysis and justification, and for incentive wage systems. While these are certainly important applications of standards, they are only the beginning. In this paper-, we will describe the methodology used and the results obtained in a pilot project for the application of labor standards in production planning. This pilot project was conducted at Peterson Builders, Inc., and sponsored by the Ship Production Committee Panel on Industrial Engineering, SP-8.

The pilot project addressed a shop loading problem, that is, the problem of deciding how much work to release to a shop for a given planning period, say one week. The estimate of work order labor content represents the single most important data element in the shop loading problem, and as such, is crucial in the interaction between planning and production. Underestimating the work content results in overloading the shop with obvious effects on performance and the relationship between production and planning. The result of overestimating the work content is more insidious, since it may lead to a general underloading of the shop. Inconsistency combines the worst of both.

Thus, shop loading is a very important activity, since it impacts directly on the working relationship between production and planning and on the productivity of the shop. Labor standards in shipyards have not been widely used in shop loading, so this represents an ideal pilot project.

## 2.0 TERMINOLOGY

Because many shipbuilders use different terms to describe the same thing, we will try to give an explicit definition for the terms used to describe the method and the case study. The reader can then substitute his own "correct" terms as required.

STANDARD TIME--The time which is determined to be necessary for a qualified workman, working at a normal pace under capable supervision with ordinary fatigue and delays, to do a defined amount of work of specified quality when following a prescribed work method. Usually referred to as a LEVEL TIME where worker pace, and allowances for personal time, fatigue and delays have already been included,

NONPROCESS TIME--On amount of time to be added to the level time to reflect additional and expected delays in accomplishing the work. Such delays may result from other work being performed around the worker, e.g., crane delays, or because the means to complete the task are not readily available, e.g., searching for material or tools.

PLANNING STANDARD--The time assigned to a particular task, including both LEVEL TIME and NON-PROCESS TIME, which represents how Iong it will actually take to perform the work (sometimes referred to as a SCHEDULING standard).

FORMULA) STANDARD--C1 planning standard stated in the form of an algebraic expression. The variables in the algebraic expression correspond to values that can be obtained readily from the description of the work to be performed.

The work order system for planning and controlling work is common to many shipyards. The manhours assigned to a work order is management's prediction of the work content of the work order. These manhours are budgeted in a manner equivalent to dollars, and become the index used for releasing work orders, measuring progress, and estimating cost or productivity. This leads to some additional terms.

RETURNED COST--The manhours charged against a work order, calculated from the time card data and available as a normal report from the accounting system.

DID COST--The true number of manhours expended for the work order, which may be larger or smaller than the RETURNED COST.

SHOULD COST--The number of manhours that the work order should require. Equivalent to the PLANNING STANDARD time. In an ideal environment the SHOULD COST would equal the LEVEL TIME,

In practice, planning standards will be different from engineered or measured labor standards. The difference must account for delays and work interruptions not directly related to the fabrication operations themselves. Some examples are: waiting time for a bottleneck operation (several mechanics need to saw at about the same time), material shortage delays, equipment malfunction, power outage, rework, and so forth.

In describing the implementation and results of the project, the following additional terms are used:

WORK ORDER--the documentation package used to describe a set of related pipe fabrications.

PIPE DETAIL--an individual sheet of a work order describing the specific material, configuration, and process requirements for one spool piece or finished assembly--also referred to simply as a detail.

ESTIMATE-labor hours budgeted for a work order by planning, based on requirements of the work order and historical return cost data for similar work on previous hulls.

## 3.0 DEVELOPING PLANNING STANDARDS

A pipe fabrication shop converts pipe stock and fittings into pipe "details," i.e., subassemblies ready for on-block or on-board outfitting. The advantages of fabricating the details in a shop are better working conditions and better access to bending and sawing equipment, thus better manpower and equipment utilization. In *order* to reap the maximum benefit from in shop fabrication, there should be accurate standards for machine and labor hours.

Two approaches to establishing planning standards are described below. The first is based on the use of engineered or measured labor standards for detail fabrication. A method *is* described for converting these level times into planning standards. The second approach does not require the availability of level times for detail fabrication but instead uses regression analysis to develop the planning standards.

### 3.1 Formula Approach with Level Times

This approach to establishing planning standards is based on the assumption that an adequate planning standard can be obtained through a simple adjustment to the existing fabrication standards or level times. This implies that the nonprocess time in the shop can be distributed to the individual work orders and pipe details in proportion to their level times, which may or may not be a valid assumption.

#### 3.1.1 Testing Proportionality Assumption

The proportionality assumption says that if a pipe detail consumes ten percent of the standard hours released to the shop for a week, then it also generates ten percent of the nonprocess time in the shop for that week. If this assumption is correct, then the standard time assigned to the pipe detail should be a very good predictor of the time that actually will be required to fabricate the detail.

*One way* to test this assumption is to obtain a sample of actual detail fabrication times and compare them to the fabrication level times using regression analysis. If there is a sufficiently large positive correlation between the level times and the actual times, then the assumption of proportionality *is* good enough to work from. Two simple models for the relationship between level times and actual times are a "ratio relationship" and a "linear relationship."

$$AT = b * LT \qquad \text{(ratio model)}$$
$$AT = a + b * LT \qquad \text{(linear model)}$$

The linear model implies that there is some nonprocess time to be distributed to each pipe detail which is not directly related to its labor content. These models were evaluated in the pilot project and the results are described in section 4.3 below.

### 3.1.2 Developing the Formula

The actual time to fabricate a detail or set of details is obviously affected by process time <average amount of time each day spent in fabrication) and by pace. Both of these, in turn, are directly affected by "shop load," or the amount of work available in the shop and planned for completion. If there is no backlog of work orders, then the pace (intensity with which work *is* done) and the process fraction will tend to decline. *As a* result, the actual time to fabricate a particular detail will tend to be greater when the shop is underloaded than when it is fully loaded. These considerations should be reflected in the adjustment to the level times to obtain planning standards,

The planning standard formula used in the pilot study was:

$$PT = LT / (PFDa * PF * SWF * SP)$$

Where:

- PFDA= personal, fatigue and delay allowance in level time
- PF = predicted shop process factor
- SWF = standard work factor; the fraction of work that is covered by standards
- SP = average shop pace factor between zero and one (a value of 1 corresponds to the pace assumed in the level time)
- LT = pipe detail level time
- PT = pipe detail planning standard

To use this formula, the level time is computed for each detail in a work order, then the corresponding planning standard times are computed. Adding all of the detail planning standards gives the work order planning standard.

This approach has several desirable attributes First, it is based on existing fabrication standards, and requires relatively little additional standard development effort. Second, it can be used to set production goals, based on best practical pace and best practical process factor, as well as to establish standards based on average realized pace and average realized process factor. Third, it can be used to guide the work method improvement effort toward reducing the factors causing delays and congestion. Fourth, it can easily be automated, so that relatively little time is required to apply the standard. The primary drawback is that this approach does require an existing base of fabrication standards.

### 3.2 Formula Approach without Level Times

A question of obvious concern to many shipbuilders is, "What can be done if there are no existing fabrication standards?" The results of this case study indicate that a similar approach can be used to develop planning standards based on actual performance rather than on fabrication standards. The approach requires the development of a regression model for predicting actual time, based not on level time, but on the pipe detail attributes themselves.

For the pipe fabrication shop, the detail attributes which most strongly affect fabrication time are:

MTL : the type of material, e.g., copper, steel, etc.;

DIA : the pipe diameter;

BND : the number of bends required;

JNT : the number of made-up joints in the detail; and

PCS : the number of pieces (pipe or fittings) required to fabricate the detail.

The values of these attributes can be determined easily from the pipe detail drawings used in the shop.

To develop the regression model, a sample of pipe details is required. The number of details in the sample depends to some degree on the form of the regression model, but in general, the more details included, the better the results. For each detail in the sample, the actual fabrication time must be recorded, either by an observer or by the mechanic. The actual time recorded must be as accurate as possible. Using the actual time and the detail attributes, a regi'ession model can be developed to predict actual time based on detail attributes:

AT = f<MTL, DIA, BND, JNT, PCS)

The specific form of the regression model may depend on the nature of the details, the organization of the shop, etc,

Once the necessary regression models have been developed, the planning standards can be determined by:

PT = AT * (SPF * SSP) / (PF * SWF * SP)

where

SPF = process factor during the sampling period;
SSP = shop pace during sampling period; and
PF, SWF, SP are as defined earlier.

Note that the ratio SP/SSP reflects the projected shop pace relative to the sampling period. If during the sampling period the shop was underloaded or overloaded, this ratio allows an explicit compensation in generating the planning standard.

This approach to setting planning standards has not been directly tested in the pilot project. However, the pilot project data has been used to verify that the necessary regression models can be developed; the resulting predictions were quite accurate. The formula standard without level times does require a substantial sampling program and sophisticated statistical modeling and analysis. On the other hand, it does not require a preexisting base of fabrication labor standards, and it can be implemented in an evolutionary process, i.e., the regression models can be refined as more data becomes available. This approach may appeal particularly to smaller shpyards with little or no in-house Industrial Engineering capability for developing fabrication labor standards.

### 3.3 Explicit Nonprocess Factors

Both approaches to setting planning standards are crude in one respect, namely, they are based on the implicit assumption that the actual time for a given pipe detail is not affected, directly, by the other details being worked concurrently. This is clearly a simplifying assumption. For example, if all the details loaded on the shop for one week required an unusually large number of bends, the bending operation could easily become overloaded, leading not only to delays;, but to forced idleness while mechanics wait on delayed jobs.

What this argues for is a system for setting planning standards that considers not only each individual pipe detail, but the entire set of pipe details in the shop at one time. This could be thought of as a standard for "congestion." For the present at least, such a system appears beyond the scope of current practice. Fortunately the simple approaches described here can have dramatic impact on productivity, as demonstrated by the pilot project results.

## 4.0 PILOT PROJECT RESULTS

The pilot project was conducted in the Pipe Fabrication Shop, Building 70, at Peterson Builders, Inc., during the seven month period from September, 1981 through April, 1982. The project team included personnel from PBI, the SP-8 Program Manager, a representative of H.B. Maynard Co., Inc. and the authors.

### 4.1 Project Baseline

Work orders are released to the pipe shop to maintain a two week shop load with a one week rollover. Estimated hours are the basis for deciding how many work orders to release each week. In

general, the shop foreman assigns a work order to a mechanic, who then works the details, more or less in order9 until the work order is completed. The work orders range between 5 and 400 manhours, with an average at about 40 manhours. The number of details in a work order varies from one or two up to thirty or forty.

One of the first project activities was to audit a randomly chosen set of work orders to compare the estimated hours to the return cost. While it was found that the total estimated hours was roughly equal to the total return cost, the individual work order estimates could be as much as an order of magnitude greater or smaller than the return cost. At this point, it was decided that both the estimates and the return cost should be included in the project analyses.

Fabrication standards have been developed in the pipe shop using the Maynard Operational Sequence Technique (MOST) and cover virtually all work in the shop with the exception of some material handling and housekeeping. These standards assume a 100% pace and include a 15% allowance for personal time, fatigue and delay.

### 4.2 Project Method

The project had two phases, data collection and analysis, and trial application. The data collection and analysis phase was to determine if the scheduling standards could be developed, and if so to determine the appropriate factors for adjusting the MOST standards to planning standards.

Data collection involved three basic elements: work order level times, actual fabrication times, and nonprocess time. The work order level times were determined initially using the existing MOST standards. Because this was felt to be too time consuming for typical use by planners9 a simplified classification standard was developed and found to perform adequately.

Actual fabrication times were determined from a time sheet filled out by the mechanic as details were being worked. The mechanics *were* instructed to work as usual, no faster or slower, with their usual method. It was assumed that the mechanics were using the proscribed standard work method. The time sheets permitted a detailed trace for a mechanic or for a pipe detail, making it easier to validate the data. The time sheets caused minimal disruption, were well accepted by the mechanics and gave very accurate actual fabrication hours.

During each data collection or testing period, work sampling was used to asses the shop's overall nonprocess time.

There were three sampling periods during the project. In the first, a sample of work orders was tracked in the shop using the time sheets, and the nonprocess fraction was estimated from work sampling. This nonprocess factor was then used to calculate a

planning standard for comparison to the estimates and the actual hours.

During the second sampling period, all work orders in the shop were tracked. Planning standards were computed using the results of the first sampling period, before the actual hours were known from the time sheets.

In the third testing period planning standards were used to load the shop.

### 4.3 Project Results

Analysis of the data collected and the returns from trial application can be summarized in four categories.

#### 4.3.1 Proportionality Assumption

The level times and actual times for individual pipe details were used in regression analyses of the ratio and linear models given in section 3.1.1. In general, the results of these analyses were positive, i.e., there was a strong correlation between level time and actual time. For both models there was a significant difference between values of the model parameters when considering material specific subgroups of details.

The linear relationship provided a better explanation of the data, for several technical reasons. It resulted in smaller residual mean squares, and its residuals were less correlated than with the ratio model.

The statistical analyses indicated that planning standards based on level times were superior to the previous planning estimates. *However*, in the statistical analyses, there is a significant amount of "unexplained" variability in the planning standard prediction of actual time. The actual causes of the variability are not known, but might include deviations from the standard method or other similar factors in addition to the natural variation in actual work element times. Even so, when the planning standards are used for loading the shop, and a number of work orders are involved, the planning standard estimate of the total shop load should provide a reasonably accurate prediction of actual time.

#### 4.3.2 Planning Standards

In all three sampling periods, the planning standards were found to be in close agreement with the actual hours reported on the time sheets, both as a total for the period, and by individual work order. In contrast9 the estimates were found to vary widely around the actual hours by work order. To be sure, the planning standards also varied around the actual hours, but to a much smaller degree than the estimates. In addition, the planning standards were uniformly smaller than the estimates.

### 4.3.3 Shop Loading

When the shop was loaded using the planning standards, the planning standard hours were found to be only 55% of the corresponding estimate hours. In spite of this "apparant" shop overload, the work orders were completed and required only 104% of the planning standard hours. This represents a fifty percent increase in shop capacity with no additional investment, simply because there are better predictions of the real labor content of the work orders with which to more properly load the shop.

### 4.3.4 Regression Models

Using the data from the three sampling periods, a regression model was developed relating actual detail fabrication time to detail attributes. This model for predicting actual time was technically superior to the model based on level times. It seems reasonable to conclude that useful planning standards could have been developed from this regression model had the MOST standards not been available.

## 5.0 CONCLUSIONS

This pilot project demonstrated that the specific method of approach used could generate planning standards that are superior to the estimates baseed only on experience and history. This is not a theoretical result--it has been proven in a shipyard shop through actual use by shipyard planners. The benefits indicated in this particular case are substantial--a fifty percent increase in productivity in the pipe shop--and the implementation costs were negligable.

In a broader sense, the pilot project demonstrated that planning need not rely only on experience and historical performance data. On the contrary, a systematic, scientific approach to planning can yield impressive results.

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# WORKER PARTICIPATION AND ORGANIZATIONAL CHANGE IN SHIPBUILDING: AN INTERNATIONAL REVIEW

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The views, **opinions,** and conclusions expressed in this paper, unless specifically referenced in the text, are represented to be those only of the author .

## Abstract

Significant innovations of a human resource nature have been introduced ***to*** international shipbuilding since the mid-60's. In the past few years, a number of U.S. yards have experimented with some of these practices (quality circles, semi-autonomous work groups, multi-skilled workers). this paper draws together information from several sources in an attempt to identify those underlying principles which have taken various forms in many shipyards in a number of countries.


## Introduction

The expression "human resources" is heard more frequently these days in American business circles; not only in the titles of business administration courses, but also in professional and department titles within industry. In some cases the content of such coursework and industry billets is much the same as was earlier encompassed under the heading of "Personnel" (e.g. recruitment and selection, training, salary and benefits administration, industrial relations, etc.). What is new, however, is an additional dimension hinted at in this more ambitious label "human resources", one that has to do with achieving the most effective use of the workforce.

"Nothing new there," one might protest, since the traditional functions of Personnel are directed to this end as are certain elements of Industrial Engineering and every other management function that touches at a11 upon the use of the workforce.

But there is a difference, and it has to do with an expanded view of the concept of " use of the workforce." This new dimension reflects the view that an organization's workforce is not simply one other element of production, but is one of the company's most important assets -- a resource that has not been sufficiently tapped under traditional management practices and organizations of work.

that the potential of the U.S. shipbuilding workforce in particular has not been sufficiently tapped, has been proposed by A&P Appledore (1980) who conclude from' a comparision of data from a sample of American and foreign yards that labor productivity in U.S. shipbuilding is generally only half that in Scandanavia and Japan (1980:1-4). Of this total they attribute 30-35% of the difference to; '...superior organisation and systems and a more effective workforce in the foreign yards" (1980:7-10).

What is also new, is the exploration and application of a number of behavioral science-based techniques (social technologies) which alter the manner in which the workforce is employed. Such modifications may range from design (or redesign) of plant facilities and manufacturing processes, to changes at the level of individual jobs and reward systems. Such

innovations *are* commonly accompanied by modification of values, sometimes referred to as "corporate culture" or "management style." that is characteristic' of these new work cultures/styles and their concrete manifestations, is an expansion of responsibilities of employees and consequent improvement in their status within work organizations. In the United States, the most generic term for this assemblage of human resource innovations is "quality of work life." In Europe *it is* called "industrial democracy" or "organizational development," and in Japan, "jishu kanri" (voluntary management).

This paper will review the development of the human resource orientation in international shipbuilding. Considerable attention will be given to the Japanese case, not because the origin of shipbuilding human resource innovations is to be found in that country, or because Japan offers the best model for emulation; but because it has been the world's leading shipbuilding nation and the principal source of technology transfer to U.S. yards. quite .simply, we know more about shipbuilding practices in Japan than we do for Europe. *Human* resource practices in European shipbuilding are also noted here, especially those of the Scandanavian yards which are generally considered to be second only to Japan. The Korean approach to utilization of the shipbuilding workforce is briefly touched upon, although very little information is available on these relatively new yards which are rapidly moving into a position of international prominence. The review will also focus on workforce utilization in U.S. shipbuilding, both in traditional practice and in specific cases of recent experimentation with quality of worklife innovations.

## Aptitude

As earlier indicated, innovations stemming from a quality of work life I orientation may take a number of forms (e.g. physical amenities, quality circles, gainsharing plans, semi-autonomous work groups, etc.). but central to the concept is the notion of decentralized decision-making, sometimes referred to as "worker participation" or "participatory management". Participatory management is based upon the premise that workers can often manage themselves better than they can be managed by echelons of managerial specialists. The logic which supports this *view* has several components.

Primary is the realization that workers -closest to the job are in many instances most knowledgeable in terms of the technical and personnel requirements of the tasks. And even if this is not always the case, any innovation or redirection in the manufacturing process is much more likely to be successfully adopted if the *workforce* has some *say* in its design and implementation.

But both of the preceeding arguments are fairly timeless ("It has always been thus"), and do ***not*** explain the 'frequency of participatory management innovations in recent ***years.*** The answer lies in a more recent phenomenon - a value change in the workforce at large. 'This attitudinal change which has been associated most particularly with the industrialized democracies has been variously identified and labeled. It is referred to by futurist Alvin Toffler as "the new ***wave",*** by sociologist Daniel Bell as "the ***age*** of entitlement", and its product, by social researcher Daniel Yankelovich0, ***as*** "the new breed". What is common to all these interpretations is the recognition that contemporary workers seek ***more*** intrinsic satisfaction from their work. than did preceeding generations for whom traditional workplace organizations and management styles were designed.

It is clear that this value shift has played ***a*** role in ***overseas*** shipbuilding. Note the comments of an American shipbuilding welding study team which visited ten Japanese yards in 1973:

> In the generally tight labor market, Japanese shipyards are finding it increasingly difficult to attract new employees. Changing attitudes of young people towards working in a shipyard environment and performing monotonous repetitive jobs such as manual and gravity welding have prompted management to explore ***new*** approaches to the recruitment of shipyard workers. For example, to improve the industry image with respect to both employees and the general public, the yards are giving increased attention to landscaping, recreational facilities, and subsidized food and housing. Auto mileage allowance is offered to some employees in lieu of subsidized housing. Women are employed in some yards for gravity welding welding and are often permitted to work individual schedules compatible with their family responsibilities (Brayton, et al - 1973:2).

That report is nearly ten years old; but even in the depressed market of the 80's, Japanese shipbuilding management is still faced with rising expectations of their workforce. A NKK manager states:

> We are not afraid of AWES (Association of West European Shipbuilders) and we are not afraid of the NIC's (newly industrialized countries). We are more worried that we won't be able to get the workers to do the dirty jobs in the future (Seatrade 1981:135).

Sectrade reports that the NKK view is not-atypical:

> This seems to be the common attitude in management throughout the Japanese shipbuilding industry -- give them the men and they will worry about getting the orders (1981:135).

Shipbuilders in the newly industrialized countries may also, to some degree, be experiencing the same phenomenon. the preresident of Daewoo, Korea's newest and largest shipyard, claims that; "The time for lower wage earners in Korea is over. But they do not work only for the money; they really care about searching for more efficiency, better productivity, better quality" (lOOA1 1982:12).

Although a higher educational level is only one element of the workforce profile ssociated with this ***value*** shift, it is interesting to note that even for shipbuilding which is not generally considered to be an industry which attracts the best and the brightest, the Asian and European yards which practice participatory management highlight the educational level of their workers.

Dr. Shinto, formerly chairman of Ishikawajima Harima Heavy Industries (IHI), points out that most of the young Japanese shipyard workers ***in the*** 60's, and almost all of them today, have received twelve years of education and are qualified for the university entrance examinations (Shinto 1980:26). Speaking of IHI's initial experience with participatory management, Shinto says:

> At the start there ***were*** various inconsistencies, but the activity took root far earlier than had been expected. It was felt that the workers, who had previously no way of realizing or instituting their own proposals and thoughts, had been given a voice in ***a very*** useful way. (A)most all workers had a twelve year education, they had their own good sense, and their participation in the improvement of the production techniques and working conditions gave them greater satisfaction in their work. The results of this program of worker involvement exceeded our expectations (1980:27-28).

Educational level of the workforce, and its potential provision of a comparative advantage in international shipbuilding is recognized ***as well*** by the Norwegians. The logic which underies a ***six*** year, nine yard, industry/government cost-shared organizational development project in shipbuilding is ***as*** follows:

> If we presume that Norwegian shipyards will continue to build and equip ships and other steel constructions for maritime use, which of these factors (products, production technology, organization-human resources, administrative systems) should be our prime objective in the endeavour to increase our competitive ability? ***Our answer*** to this is organization/human resources. Technology as such is international in character and easily transferable between countries. Not so with human resources. The possibilities of releasing the productivity potential of human resources depend much more on national conditions. Consequently, our relative competitive ability will primarily depend on how well we succeed in doing this. In our opinion we have ***a*** good basis for this in Norway. The general level of education is high, and relations between the main parties in economic life are comparatively good. Therefore, we should direct our efforts towards making the most of these advantages (Westhagen and Hotvedt 1980:18).

Education as a human resource advantage in shipbuilding may not for long be the province only of the industrialized nations. As the managing director of Korea Shipbuilding and Engineering reports for his firm; "We feel that education is very important here, and all the workers have 15 minutes of English lessons each day. (W)e don't do this only to teach them shipbuilding terms; we want them to learn basic English" (lOOA1 1982:14).

By comparison, the educational level of U.S. shipyard workers is probably lower than in Japan or Scandanavia. As of 1970, 52% of American shipyard workers had completed high school and six percent were college graduates (figure 1). And this might suggest that the U.S. shipyard employee would be less inclined toward, or capable of, self management than his *overseas* counterpart. the fact that participatory management was earliest realized within Japanese and European yards (since the late 60's) may be supporting evidence. But the general population surveys upon which the notion of worker dissatisfaction is based, have been conducted *in* the United States *as* well as overseas. A study by the U.S. Chamber of Commerce shows that 80% of American workers today believe that they could improve productivity if management would only listen to their ideas (U.S. House of Representatives 1981:12).

Figure 1

EDUCATIONAL ATTAINMENT OF EMPLOYED MALES IN SELECTED INDUSTRIES, 1970

| Industry | Percentage of Employed Males a/ Completing years or More of: High School | College |
|---|---|---|
| Construction | 43.8 | 3.9 |
| Manufacturing. | 55.8 | 9.9 |
| Du1rable Goods | 56.5 | 9.6 |
| Motor Vehicles | 54.1 | 5.7 |
| Aircraft | 73.0 | 18.5 |
| **Shipbuilding and Repairing b/** | 52.3 | 5.7 |
| Private Wage and Salary Workers | 48.6 | 5.7 |
| **Government** Workers | 60.5 | 5.9 |
| Railroad Equipment | 54.5 | 5.7 |

a/ Age 16 and over.

b/ Includes boatbuilding and repairing.

Source: Bureau of the Censug

Other evidence of American worker interest in, and capability for, self management is found in the number of quality of work life programs in U.S. industries (auto, steel) whose workforce educational profiles are not unlike that for shipbuilding. Such programs are prospering, even in the U.S. construction industry which has the lowest educational profile of the industries appearing in Figure 1 (Ross 1981). What is most interesting about Figure 1, is the sizeable difference between the educational profiles of the private and naval yard workforce. Whereas only the construction industry has a lower level than private shipbuilding, the naval yards are fully 12 points higher and are exceeded in the category of manufacturing only by the aircraft industry.

Another revealing, though isolated statistic, suggests a considerable shift in the age and education of at least the naval yard workforce. Forty percent of the apprentices enrolled in Pearl Harbor Naval Shipyard's training program have completed between 2-4 years of college (Hartigan 1982). These. statistics may explain why it is that the naval yards were the first ***to*** experiment with participatory managment in U.S. shipbuilding. They may also suggest that lower educational levels may have been only a braking rather than disqualifying factor.

Within the past two years, at least three private yards (Bethlehem Sparrows Point, Lockheed, and Sun) have been experimenting with, or implementing, participatory management programs. Of the two that survive, Lockheed reports substantial success Hayes 1982) (Hayes and Swanson 1981) (Smith 1982) while Bethlehem's program is too new to call (the first meeting of the Employee Involvement Group was held this Spring). The Sun project was nearly two years old when it was discontinued by new management upon purchase of the yard. Union officials and the previous management were ***very*** enthusiastic over the results of the project, which was in the process of expansion at the time of the sale. It is reported that the local union and yard workers are encouraging the new management to reinstitute the program (Lazes and Laird 1982). These three examples are based only upon the personal knowledge of the author which does not proceed from any formal - ***or*** informal survey. There may well be other private U.S. yards that are quietly experimenting with partipatory management styles and new organizations of work.

but there is also evidence of widespread worker dissatisfaction with non-participatory management styles in American shipbuilding. The result of interview and questionnaire analysis of 13GO production workers and professionals in ten U.S. yards revealed that:

> (M)any believe that their company's management has no interest in them as persons, is unaware of what they do, and is oriented to machines rather than people. Most hourly production workers believe that they do not influence the company in any important ways. The fewer than twenty percent of the workers who believe their influence is important perceive that influence to come primarily in the way they perform their own job. The majority of workers who believe that they cannot influence the company in important ways cited that it was futile to try, that the company didn't care or was too tig or set in its ways, or that their low position. or lack of knowledge prohibited their influence (Meunch 1976:4).

> (E)ven more important to the professional group is what they believe to be an unhealthy company attitude in the sense that they perceive the company to demonstrate little interest, respect or appreciation to the professional worker (1976:3-43). (O)f all the personnel groups. fewer of the professional workers perceive that the company gives them the feeling that they are important in getting the job done, and fewer than one-half of the professional group believe that they can influence the company in any important way. The professional group has the greatest predilection *to* consider moving to another company and, along with job availability, a primary cause for this need for mobility is the professional's perception that the company doesn't care (Meunch 1976:3-45).

To briefly summarize this point, the "aptitude" logic or argument for participatory management, while perhaps stronger in Japan and Scandanavia, yet obtains for U.S. shipbuilding, even in the private sector. Forms of participatory management are now being experimented with and adopted here as well. There has been a delay, *to* be sure, but there has not been any program failure on the basis of deficiencies in the self-management inclination or capacity of American shipyard workers.

## Participatory Management

One manifestation of participatory management that has received *more* U.S. attention than any other, is that of quality control circles. Quality circles have. their origin in the Japanese modification and application of Western principles of; diffuse management responsibility for quality, statistical techniques, and behavioral science concepts of organizational development. The new twist added by the Japanese was the extension of quality control jurisdiction and responsibility to every individual in an organization through the vehicle of small study groups -- this in contrast to the traditional practice of relying upon specialist quality control engineers.

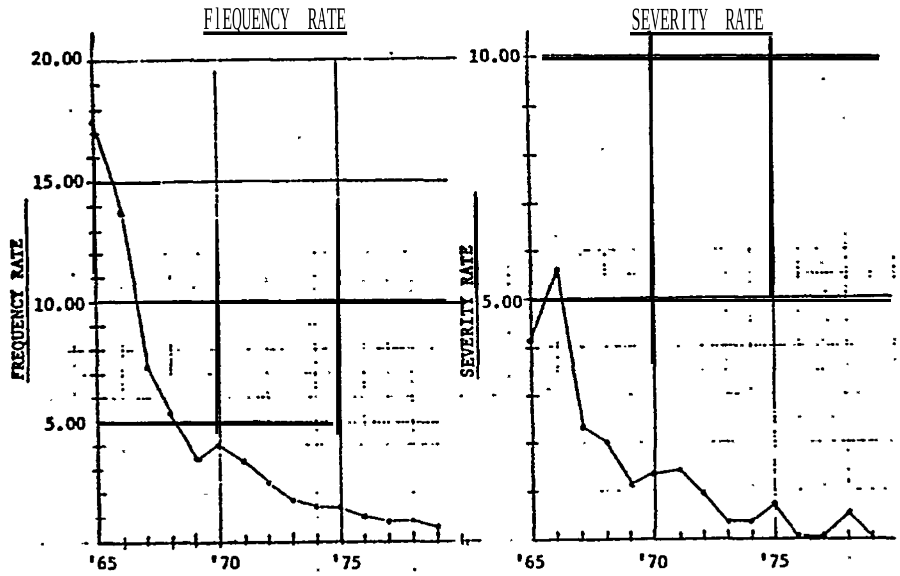
The quality circle concept was not, therefore, an element of traditional Japanese culture, but had very definite beginnings in the early 1960's as Japanese 'management moved toward adoption of worker participation in decision-making and "small-groupism" (shoshudanshugi). Similar workplace experiments in Europe were observed by the Japanese, and by the end of that decade small group participative management practices were widespread throughout Japanese industry. A 1968 survey of 850 manufacturing companies revealed that 73% were practicing some form of participatory management through small groups. The shipyards *were* among the first industries to experiment with the new technique. That same year, the president of Hitachi Shipbuilding, speaking at the Annual Meeting of the Japan Federation of Employers' Associations (Nikkeiren), could give *a* progress report on his company's experience with all-employee management participation (Cole 1979:134).

Nor did the Japanese quality control circles address quality issues only. In 1968 the Union of Japanese Scientists and Engineers reported that the existing circles were focusing only half of their attention on quality control narrowly defined. Forty percent of circle activities dealt with productivity .and cost reductions, While ten percent was devoted to safety matters (Cole 1979:134).

In shipbuilding it was "safety" and not "quality" or "productivity" that was the first concern of the newly initiated small group movement. The industry in the mid-60's was very concerned with the escalating frequency and severity of yard accidents due, in Shinto's opinion, to the fact that the expansion and competitive position of Japanese shipbuilding at that point had been "...based on the physical energy of the workers" (1980:26). Compulsory enforcement of safety measures provided only temporary improvement, and it was not until the introduction of the small groups, and management's immediate attention to the problems identified by them ("...regardless of expense...") that a steady long-term improvement of safety records was realized (Shinto 1980:22). At IHI, the success of the initial safety effort led to the expansion of the small group program to the full yard by 1972-74. This dramatic and continued safety improvement is depicted in Figure 2. Perhaps an even more dramatic statistic is that there occured in 1980 less loss-time accidents in all the Japanese yards than in one single American yard (Gilbride 1982) -- and the total tonnage delivered for all American yards that year was only about one-tenth that of Japan (maritime Administration 1981) (Naval Sea Systems Command 1981).

Figure 2

Frequency and Severity of Shipyard Accidents at IHI
1965-1980




- accident frequency in worker injuries per million working hours
- accident severity in working days lost due to accidents per thousand working hours

The small groups in shipbuilding, like their counterparts in other Japanese industries, did not limit themselves to a single problem area. As Shinto explains; "(P)roductivity is the result of the combination of three elements: safety control, quality control, and efficiency control (1980:28).

Participatory management was introduced into the Swedish Kockums yard as a result of the findings of the "Kockums Report" (1970). This self-study revealed that the root of the yards's ***severe*** personnel problems was a new piece-work standards system which was introduced in 1967 with the transition from conventional shipbuilding to the factory-shipyard concept. As a,result of organizational changes made based upon the Kockums Report, including participatory management, labor turnover rates dropped by one-half and overall productivity was improved by a third (Hill 1973:51). In Norway, worker participation (along with improved physical conditions and improved recruitment and retention) has been a central aim of the Norwegian shipbuilding industry (Westhagen and Hotvedt 1980:14).

Although the U.K. lags Europe in its experience with participatory styles of management, there has been movement in this direction. Speaking of the U.K. shiprepair industry, Nichols of the Tyne Shiprepair Group reports that a number of shiprepair companies now have joint monitoring arrangements ***or*** workforce involvement as shareholders or participants in profit-sharing schemes. In Nichols opinion:

> There cannot be lasting improvement within the (U.K.) shiprepair industry without further development of more open and participative styles of management. Industry is a joint venture, and in an ailing one like shiprepairing it is more essential than ***ever*** to ensure that everyone understands the problems and the reasons for the changes that ave to be made in the interests of survival (Flack and Nichols 1980:38).

Returning from a visit to Japan, Chalmers, General Secretary of the Boilermakers Society, observed that consultation between management and - workers could go a long way, towards helping the U.K. shipbuilding industry match the severe competition from Japanese shipyards; "We can beat the Japanese at their own game, but it has to involve greater motivation of our workforce" (Fox 1980:2).

In U.S. shipbuilding, participatory management has taken the form of several variations on the quality circle theme.

Norfolk Naval Shipyard was perhaps the first U.S. shipyard to experiment with participatory management. The 9 quality circles initiated in 1979 were also among the very first in the federal government, and the Norfolk program has been serving as a model for other government agencies and private industries. In their second year of the program, Norfolk expanded the number of circles to 62. Perhaps more appropriately named than similar groups in other shipyards and industries, the Norfolk quality circles have in fact focused primarily on "quality" rather than "safety" or "productivity". Although Norfolk, like all the other u.s. shipyard

programs, ***stresses*** that the payback has been realized most dramatically in the improved self image of the employees, a quantitative accounting has reported a 1:3.8 cost/benefit (Tweedale 1981:363). Other naval 'yards (Puget Sound, Philadelphia) have followed Norfolk's lead in installing quality circle programs (Bradley 1981).

The Sun Shipbuilding quality of work life program, initiated in 1980, also entailed "problem solving teams" involving 175 workers in three departments of the yard. An independent accounting of that program's activites by the yard's industrial engineering department identified over $600,000 in savings in the first year (Lazes and Laird 1582).

Also begun in 1980, Lockheed's new work culture (they do not consider it to be program in the sense of an experiment or application of specific techniques) has now 38 circles which are the main vehicle around which a much larger and more pervasive quality of work life environment has been formed. Eschewing tradtional Japanese quality circle training in statistical techniques, Lockheed has oriented its circle activities in the direction of work planning. What is particularly unique to the Lockheed approach (cf. other U.S. shipbuilding participatory management programs) is the relationship of the quality circles ***to the*** remainder of the organization. They do not form a separate and parallel chain of authority and responsibility within the firm (there is no labor-management program steering committee), but constitute part of Lockheed's formal management structure. What is also unique in the Lockheed program is the effort put into the development of white collar circles. One-half of this yard's circles are constituted of office, rather than production, workers. Examples of quantified results of circle activity include; a painters and scalers circle which discovered deficiencies in sandblast material which upon rectification resulted in improved steel surfaces and a $68,000 yearly savings in material costs; a pipefitters circle redesigned the layout of their shop which translated into a 20% reduction in new construction pipe-fitting man-hours; a welding circle developed a new process to use weldable zinc primer which saves the yard several thousand man-hours per year (Hayes and Swanson 1981:94)

The shipbuilding organization which has most recently introduced a participatory management program is Bethlehem Steel. The Sparrows Point facility is the pilot shipbuilding project in that corporation's much wider effort in ***a*** number of industries. The first three "employee involvement groups" were formed this past Spring.

## ***Organizational Change***

The introduction of participatory management, in itself, constitutes an organizational change; but such forms as quality circles and joint labor-management employee involvement steering committees constitute a sort of parallel structure to the principal formal hierarchy (in many instances

***to*** increase its effectiveness) (Davidson 1982:13). However, organizations have frequently gone further in modifying the structure of formal tasks, management systems, and reward systems along the same lines of decentralization and flexibility.

One element of the orienting philosophy of the Norwegian shipbuilding organizational development project is that; "...organizational development processes have to be coordinated with other development processes within areas such as product, production technology, and production systems" (hesthagen and Hotvedt 1980:14). This highlights ***a*** difference between the earlier "human relations" approach to personnel development (tender Loving care) and quality of work life innovations, which ***are*** rooted firmly in technological and production realities.

In this respect, the Norwegian view is very similar to that of the Japanese. In that country, participatory management did not take the form only of occasional study groups, but rather was incorporated in a manner that supported changes in the larger organizational framework, the structure of shipbuilding work itself. In the Scandanavian yards, the change has consisted of a movement away from the traditional piece-work system (Westhagen and Hotvedt 1980:16) (Hill 1973:50). In Japanese shipbuilding, organizational change has taken the form of small rather than large groupings of workers.

Riesenfeld, in a survey of computer use in Japanese shipbuilding observed:

> The workforce is well organized into small working groups which ***are*** autonomous in the labor division within each group. These are called multi-functonal workers, and their experience indicates that these groups show increased productivity which results in better worker morale (1978,appendix 3:3-4).

This small group innovation may be viewed as an adaptation ***to*** - product-oriented work breakdown production processes. Shinto, in his narrative of the progress of production techniques in Japanese shipbuilding, reports that; "The new system of production in Japanese yards did not find a complementary workforce organization in place. The workers were purposefully retrained and reorganized (1980:27). "(I)eam organizations of the Workers ***were*** suitable altered from functional control to zone control" (Shinto 1980:16). Rather than moving individually all over a ship, workers under this arrangement remain together as a team working sequentially on similiar modules in a particular workstation. The predominance of small group organization in Japanese yards is evidenced by a comparatively higher supervisory index (1.45 supervisors to 4.5 workers at IHI vs. 1:lO.g at Levingston)(Colton and Mikami 1980:70).

The concentration of individual worker attention to a specific workstation might seem at first glance to run counter to job enlargement practices which have accompanied the introducton of small works in other manufacturing settings. In the *case* of shipbuilding, however, each task may consume a number of hours and *gives* the worker ample opportunity to exercise skill and discretion (Colton and Mikami 1980:56). Levingston reports that their experience with the small group/workstation innovation (part of a technology transfer program with IHI and MarAd) *has* been "...exceptionally well received by production personnel" *(Colton* and Mikami 1980:54-55). This *same U.S.* yard has attempted to stabilize *the* membership of workstation *teams* by making permanent assignment of individual workers to specific supervisors (Colton and Mikami 1980:70). Although Levingston did not report that it experimented as wel1 with participatory management at the time of introducing these organizational changes, it did state that:

> In general, the features that characterize Japanese shipbuilding technology and make it uniquely different are philosophical in nature. It is a philosophy of management and control that works very well with a group-oriented and highly motivated workforce (1980:72).

The fact that participatory management frequently takes the form of small study groups, and that this also happens to be an important direction taken in terms of shipbuilding organizational change is not unconnected. The link has to do with the fact that people frequently do their best work in small assemblies, whether that work be "head work", "hand work" or some combination of the two. In Japanese shipbuilding, the small study group and the actual working crew have the same membership.

However, the principal relationship between participatory management and organizational change (which may take a number of forms depending upon specific social and technological conditions) is to be found in the ability of organizations designed around the principle of participation to respond more easily to change. Structural provisions for participation in decision-making provide a degree of organizational flexibility that is absent in companies that structured along strict hierarchical and bureacratic lines. Participatory organizations have more ears attuned to signals of the necessity for change, and are less susceptible to delays occasioned by the "not invented here" syndrome.

These related concepts of organizational decentralization, de-bureacratization, and flexibility are quite topical in today's shipbuilding industry. Appledore and Rosenblatt make the *claim that:*

> *One* of the *greatest* differences in contemporary shipyards is the degree of organisation of work and its effect upon the productivity of the man. The high craft skill possessed by some shipyard workers has enabled the adoption in the appropriate companies and countries of a minimum of formal organization. This circumstance is usually accepted by the management in search of a great deal of flexibility (1980:10-3).

The characteristic organization of U.S. yards is at the other extreme in this matter of flexibility. The 1978 survey and comparison of U.S. and foreign shipbuilding technology levels included a category "Organisation and Operating Systems". Although the multi-element comparision resulted in overall similarity between U.S. and foreign levels in this category, one constitutent element of that classification showed a major divergence, the one concerning flexibility in the assignment of work and supervision of the workforce. Whereas the American yards are characterized ***as*** rigidly bound by trade structures, their foreign counterparts are described as having either "high levels of flexibility and interchangeability", or "maximum flexibility through workstation organization" (Marine Equipment Leasing 1979:111-32);

Ihis rigidity of organization is not a problem that is peculiar to American shipbuilding, but is characteristic of U.S. industrial organizations in general. It has been traced, to a large extent, to the influence of "scientific management" as developed by Frederick Taylor and institutionalized in the form of industrial engineering. It has to do with the concept of a "job". Scientific management encouraged the precise and formal description of jobs based upon techniques of task analysis and work measurement. The more circumscribed each job description, and the fewer tasks entailed, the better for purposes of assignment of standard production norms. This one-dimensional, hierarchical, and bureaucratic management approach was complemented and reinforced in the United States by the newly forming unions' interest in unambiguous and discreet job classifications for purposes of operation of a strict seniority system (Piore 1974:81).

It appears that shipbuilding in Japan may be even further advanced in this direction of Workforce flexibility than other Japanese industries. In their comparative analysis of three modernized Japanese companies (saki distillery, appliance factory, and shipyard), Marsh and Mannari ***were*** particularly struck by the emphasis on job diversification in shipbuilding. Both in their interview and questionnaire response, the majority of the shipyard workers voiced a preference for multi-skill jobs (1976:83 & 91-92). Again, as with participatory management practices, job diversification and multi-skilling are not part of traditional Japanese culture. Ihe change is more recent, as a shipyard personnel manager explains:

> Between 1950 and 1963 we made revisions in the rules of job and authority seventeen times. Then, after 1963, we gave up the attempt to rigidly specify definitions of job and authority. In practice, we threw out rigid authority over jobs (1976:48-49).

Marsh and Mannari note that flexibility extends to managerial levels as well, especially in middle management ranks. Indicative of the change in emphasis is the elimination of the title "section chief" and substitution of the term "team leader" (1976:SO).

The same researchers report that the shipyard they studied had also introduced some aspects of a matrix or task force type of organization; "...with team leaders and workers brought together on a temporary basis to solve a particular problem or accomplish a particular job, after which they are disbanded" (Marsh and Mannari 1976:50).

Shinto, in his description of the progress of production techniques in Japanese shipbuilding, reports that the change in workforce organization from functional to zone control;

> necessitated a ***drastic*** change ***in*** the combination of worker skills in each team. Workers were retrained so that 'they could manage to do multiple jobs or at least tack weld and gas cutting in addition to their proper jobs (1980:16).

The Scandanavian shipbuilders, experiencing high labor costs, have also deve1oped a highly skilled and high productivity workforce operating under the principle of flexibility and interchangeability. Such practice makes ***most sense*** in those countries and industries in which ***a*** comparatively ***narrow*** wage range encompasses the skilled, semi-skilled, and unskilled workers (A&P Appledore 1980:3-7).

The British shipyards, who have gauged their performance against the considerably more productive European yards, refer enviously to "continental style" working arrangements based on full flexibility limited only by the competence of individuals to carry out work assignments.

> The principle of one man, one trade, one set of skills, is no longer viable. What is required of tomorrow's tradesman is that his skill and knowledge should be multi-faceted and that full use should be made of the whole range of an individual's intelligence and potential skills (Flack and Nichol 1980:37).

In the U.K., where craft demarcation lines have been rigidly drawn, a number of yards have negotiated with their unions "continental style" working practices. In the U.S., Penn-Texas' Pennsylvania yard has recently announced a contract in which the number of labor grades has been reduced from ***over*** 400 to approximately 80, with craft departments cut from 65 to 13. It is reported that work rules have been completely eliminated at the yard (Journal of Commerce 1982:12A).

Another related element of Japanese shipbuilding organizational change **has to do with decentralization of professional staff functions. At IHI:**

> (P)roduction engineering is a function of the production workshops, each of which has its own Production Planning and Engineering Group. 'These groups are each made up of a staff of engineers who are responsible for specific activities related to the optimum utilization of facilities, processes, and manpower on each hull construction project. This activity includes the analysis and continual improvement of procudtion processes to realize improved productivity (Colton and Mikami 1980:30).

It is this continual analysis of the production engineers working in close contact with the production workers that serves as the basis for refinement of detailed working drawings, procurement specifications, and materials lists.

> In this regard there is a great deal of collaboration between designers and workshop "staff" engineers. Production information is an integral part of the development of the working drawings and production engineers provide a continuous feed-back of data to improve the usefulness of the drawings for the production workshops (Colton and Mikami 1980:30).

Although Levinston reports an independently invented production workshop structure similar to that of IHI, the American yard has retained centralized rather than dispersed engineering staff functions (Colton and Mikami 1980:67). Avondale has moved in this direction by holding weekly meetings between engineering and production groups for the purpose of reviewing plans (Mongelluzzo 1981:11A). Although considerable interest has been generated in U.S. shipbuilding circles for design/production integration, concentration has been in the development of an electronic interface (CADCAM) rather than on organizational change.

Similarly, Colton and Mikami describe as "striking" the IHI system of decentralization of scheduling. Again, the staff engineers that perform this function are found at various levels of the hierarchy, yet manage to produce schedules of different degree of detail that agree with each other. The Levingston approach, in contrast, entails scheduling at the gross level by the Central Planning and Control Department, and at the detailed level by the Production Planning and Control Department. Levingston has announced its intent to experiment with decentralization of detail planning (Colton and Mikami 1980:57).

On this subject of flexibility, the survey of shipyard worker job satisfaction revealed that the most common spontaneous production worker complaint related to "working conditions" did not have to do with shortcomings of the physical facilities. Rather, the workers complained of poor planning, schedule coordination, and communications (both between - crafts and between production workers and staff services) (Meunch 1976:3-9)..

As might be expected, the much younger quality of work life projects in U.S. shipbuilding have not progressed so far as those of the Japanese or Europeans in this matter of organizational change. It would seem that these several programs have followed a very similar progression from early development of multi-craft study groups, to subsequent self-managing action groups constituted of continually associated workers. The brand-new employee involvement groups at Sparrows Point are mu1lti-craft affairs, and Lockheed's first circles had membership mixes of various trades, professionals, and managers. But the Lockheed circles are now evolving toward a craft and supervisor orientation. The yard reports that these newer Workgroup quality circles are beginning to pursue problems of a more

complex and company-wide nature (Hayes and Swanson 1981:94). When this happens, quality of work life becomes no longer a one hour per month activity (quality circle meeting), but is a 40 hour per week endeavor which can lead to-much more significant organizational changes and productivity gains.

Perhaps the best example of this progression is to be found in the Sun project. As a later experiment in that yard's quality of work life program, a group of production workers were given complete management control over the construction of a main deck section module. The experiment allowed this fabrication group to do its own planning and production with supervision and specialist staff intervention only as requested. Besides introducing some production innovations of an engineering nature, the workers achieved efficiencies through inter-craft cooperation. The savings in man-hours over the construction record for an earlier identical module was in the order of 50%, and absenteeism dropped from 15% to less than 2% (Sun News 1982:5). The president of the union local said of this experiment:

> Before, management told you what job ***to*** do, when to do it, and how to do it. They didn't look to input from workers. E-10 (the project deck module) was completed with very little input from supervisors, and inspectors told us it was the best quality work they could remember (Sun News 1982:5).

## Summary

The preceeding studies, reports, news items, and comments, suggest strongly that participatory management and small group/multi-skill worker organization has contributed substantially to productivity improvement in overseas shipbuilding. Results of three ***years*** of experimentation with, and tentative implementation of, similar innovations in American yards indicate that they might also work well in this country.

But in U.S. shipbuilding, and in other industries, one frequently hears caveats about transfering management styles and organizational forms from ***overseas,*** especially in the case of Japan, because of cultural differences. What is often overlooked, however, is that these practices are not part of the traditional heritage of these countries and have been implemented and diffused as a result of purposeful introduction and successful tentative experimentation. As has been shown for shipbuilding, participatory management and such organizational innovations as small production teams and multi-skill workers have very clear points of practical origin in the not-to-distant past. Even the practice of lifetime employment has had a relatively short history in Japan. It developed as a solution to problems experienced by the large firms during the Mejii Restoration. The shipyards, in fact, served as the prototypes for emergent Japanese employment practices

such as the permanent employment system (Dare 1973:380). And the conceptual origins of these practices is frequently to be found in Western, or even American, behavioral science. It is ironic to hear that there are voices in Japan critical of unreflective borrowing of European concepts of worker participation (Cole 1979:8).

A related view is that it is not these new techniques, but rather the underlying elements of social organization that result in high levels of performance (e.g. Japanese paternalism, company housing, participation in company activities, company identification). Marsh and Mannari's study found, however, that these distinctly Japanese Social organizational variables have less causal impact on performance than do the more universal social organizational variables such ***as*** employee status in the company, job satisfaction, etc. Their conclusion is that; "Performance in Japanese firms appears to have the same causal sources as in Western firms" (1976:335).

But in rejecting the view that these human resource practices are 60 culture-bound that they are not transferable to the U.S. (and that the distinctly foreign patterns of the larger social organizations are critical to the success of these industrial practices), the opposite error should not be made -- that these innovations were institutionalized overseas as isolated "events". Industry management styles and organizational forms in Europe and in Asia have indeed been altered in the direction of greater worker participation, small production groups, and organizational flexibility. But it has ***occured*** as a "process" by means of which theories and practices (whether of foreign or domestic origin) have been experimented with, modified, and melded into various social, political, economic, and technical environments. It did not occur by means of extracting out of context single elements or social technologies (quality circles, autonomous work groups, etc.) from other nations or other industries. Ihe degree and forms of worker participation in the United States will not take shape overnight, and will quite likely be easily distinguishable from those in Northwest Europe and from those in Japan. At the same time, the particular form of work groups in U.S. shipbuilding may have more in common with shipbuilders abroad than it will resemble what is developing in U.S. steelmaking or auto.

Perhaps indicative of the culture of U.S. shipbuilding, is the very considerable difference between U.S. and overseas attention to the physical environment and amenities of the yard. It was in this category "Environment and Amenities" that the 1978 survey and international comparison of shipbuilding technology levels revealed the largest U.S./foreign disparity. While some of the large-scale environmental deficiencies of the U.S. yards may be attributed to their age, Lowry, Stevens, and Cragg note that inferior amenities such as canteens, washrooms, toilets, lockers, etc., could be fairly easily remedied by local management initiative (1980:164,162). In contrast, they point out that the high standard of amenities provided Japanese and European shipyard workers ***are*** either demanded by the workforce, ". ..or are provided by the company for other reasons" (1980:164). As has been demonstrated, those "other reasons" have to do with attracting and retaining ***a*** high quality laborforce, one suited to new ways of working.

Hood, in a review of the Lowry, Stevens, and Cragg analysis of the Appledore survey, rises to the defense of the U.S. shipyards, pointing out that industry has actually done quite well in technology upgrading in spite of political; social, and environmental factors over which the industry has little control. He gives three specifics:

1) costly U.S. regulations and standards, more stringent than those found abroad,

2) the comparative negligence of government stimulus and assistance in the United States, and

3) the differences in shipyard work practices, motivation, and ethics (Lowry, Stevens, and Cragg 1980:169).

Granted, the first two problem areas may be of a sort that do not lend themselves to unilateral action on the part of industry. It is not so clear in the latter cases, however, that industry cannot on its own, and without need of larger coalitions, modify its own work practices and improve the motivation of its own workforce. To the contrary, industry leadership may innovate in the way the workforce is organized and used -- through individual initiatives, joint labor-management experiments, and collective bargaining.

The alternative is to continue with the traditional arrangement in which:

engineering, planning, and scheduling are accomplished only by centralized specialists,

development of safety improvements is the exclusive responsbility of safety engineers,

quality is the reserved function of the quality assurance department,

production workers (and even professionals) perform only a limited range of tasks and no others, and

problem solving and decision making remain the sole preserve of full-time managers,

The record thus far suggests that individual competence, and not bureaucratic boundaries, should set the limits of employee participation in technical and management tasks. It appears that this may be the key to turning a workforce into a human resource.

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# COMPUTER INTEGRATED SHIPBUILDING: A FRAMEWORK FOR TECHNOLOGY MODERNIZATION

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Senior Associate Consultant
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Mr. Snodgrass specializes in strategic and tactical management consulting services for advanced CAD/CAM technology with emphasis on program management, capital resources, information resource management and human resource planning. DACOM clients include major corporations and their subcontractors throughout the United States. He has more than 25 years of experience in the manufacturing industry. His experience covers the gamut of manufacturing functions, ranging from product design to "bottom-line" business management. Included in his background is exceptional firsthand experience in such areas as manufacturing engineering, production planning, materials planning, proposal management, and management information systems. Additionally, Mr. Snodgrass has been personally instrumental in introducing advanced state of the art practices into a number of manufacturing environments, including CAD/CAM, Group Technology, and Quality Circles.

Mr. Snodgrass is a Mechnical Engineer and is an Executive Program Graduate of the UCLA Graduate School of Management.

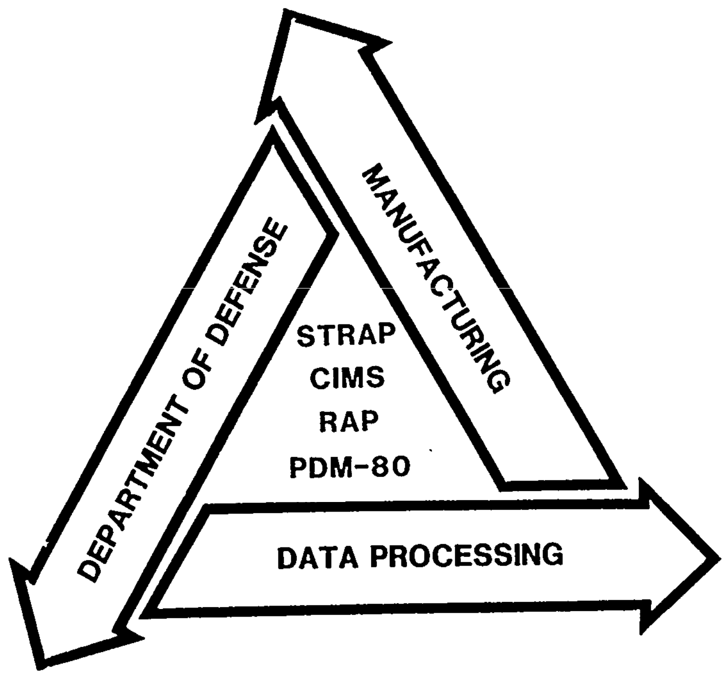
## ABSTRACT

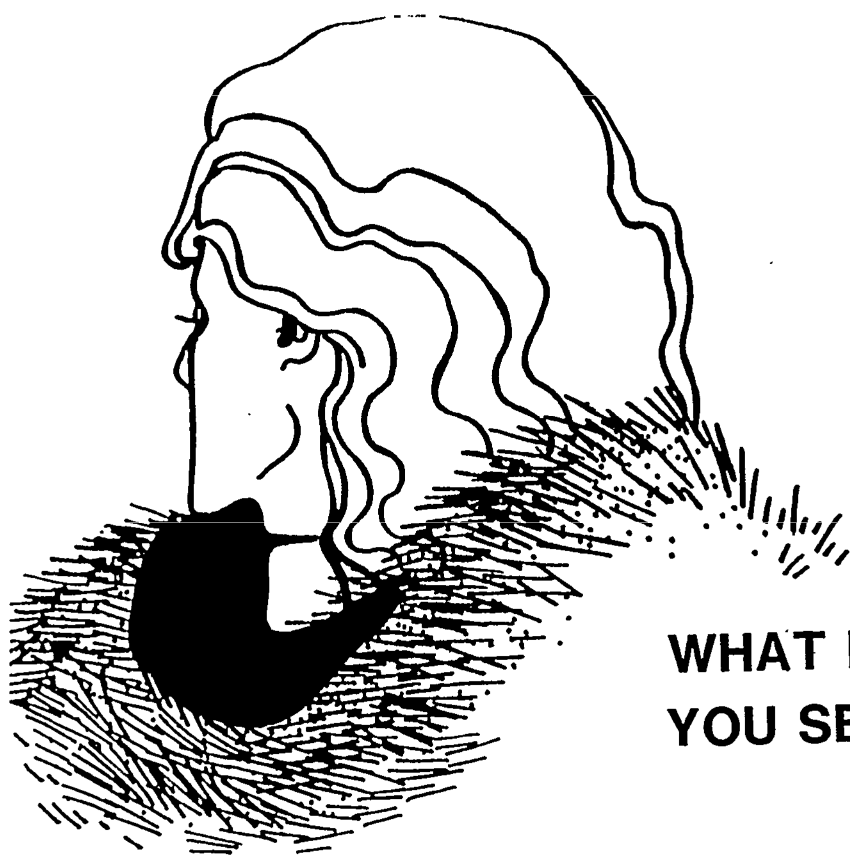
Computer Integrated Shipbuilding (CIS) systems represent a key technology for improving the U.S. shipbuilding industry in the coming decades. CIS will be based upon a completely integrated CAD/CAM system that provides computer control or assistance to all shipbuilding functions. The shipbuilding aspects embraced by CIS include business planning and support, engineering design and ship production planning, control, and automation. All business functions of marketing, ship delivery, and logistics support can be linked into such a CIS system.

The objective of this paper is to provide a framework for shipbuilding technology modernization which incorporates a road map for the integration of shipbuilding functions via systematic planning and the simultaneous systematic application of computer technology.

This CIS approach is unique in that it is data driven and is based upon a three architecture concept. This concept concentrates planning methodologies on building three formal integrated architectures: (1) the "application and database architecture", defining what applications and databases must be implemented to support the using. community; (2) the "computer systems architecture" on which those applications and databases will be implemented; and (3) the "control architecture" which defines specific project and software management techniques to be used to implement and maintain the applications within the computer systems architecture. Each of the architectures is ultimately represented in the form of standards and procedures.

# DACOM



WHAT DO YOU SEE?

## "CAD/CAM APPLICATIONS IN THE CONSTRUCTION OF NAVAL VESSELS" WORKSHOP

- 0 IDENTIFICATION OF **STP PROGRAM PROBLEMS & OPPORTUNITIES**
- 0 **POTENTIAL TECHNOLOGICAL & MANAGEMENT STRATEGIES**
- 0 **ROLE OF COMPUTERS IN SHIPYARD INFORMATION MANAGEMENT**
- 0 **APPLYING TECHNOLOGIES & ORGANIZATIONAL FORMS FROM OTHER INDUSTRY SECTORS**
- 0 **STRATEGIES FOR DEVELOPING THE NEXT GENERATION OF COMPUTER AIDED SYSTEMS**

## [C] OMPUTER [I] NTEGRATED [s] HIPBUILDING

- **o COMMON TERMINOLOGY & CONCEPTS**
- **o PRODUCTIVITY 'MYTHS" AND "DISCOVERIES"**
- **o CHANGING MANAGEMENT FOCUS**
- **o INFORMATION RESOURCE MANAGEMENT (IRM)**
- **o DATA' DRIVEN IRM ARCHITECTURE**
- **o MANAGING CIS FOR TOMORROW**

# COMMON TERMINOLOGY

- FRAMEWORK
- ARCHITECTURE
- STRUCTURE
- "BLUE PRINT"
- "ROAD MAP"

# COMPUTER INTEGRATED MANUFACTURING

- MANUFACTURING, WHICH BEGINS WITH PRODUCT DESIGN AND ENDS WITH SUPPORT AND MAINTENANCE IN THE FIELD, IS A MONOLITHIC, INDIVISIBLE FUNCTION. --- NO PART CAN BE SUCCESSFULLY CONSIDERED IN ISOLATION FROM ALL OTHER PARTS.

- DIVERSE AS THE VARIOUS PARTS OF MANUFACTURING MAY SEEM, THERE IS A COMMON THREAD THAT RUNS THROUGH THE FULL SCOPE OF ALL MANUFACTURING ACTIVITIES. -- MANUFACTURING IS, IN THE ULTIMATE ANALYSIS, A SERIES OF DATA PROCESSING OPERATIONS.

DR. JOSEPH HARRINGTON
1990 CAD/CAM CONFERENCE

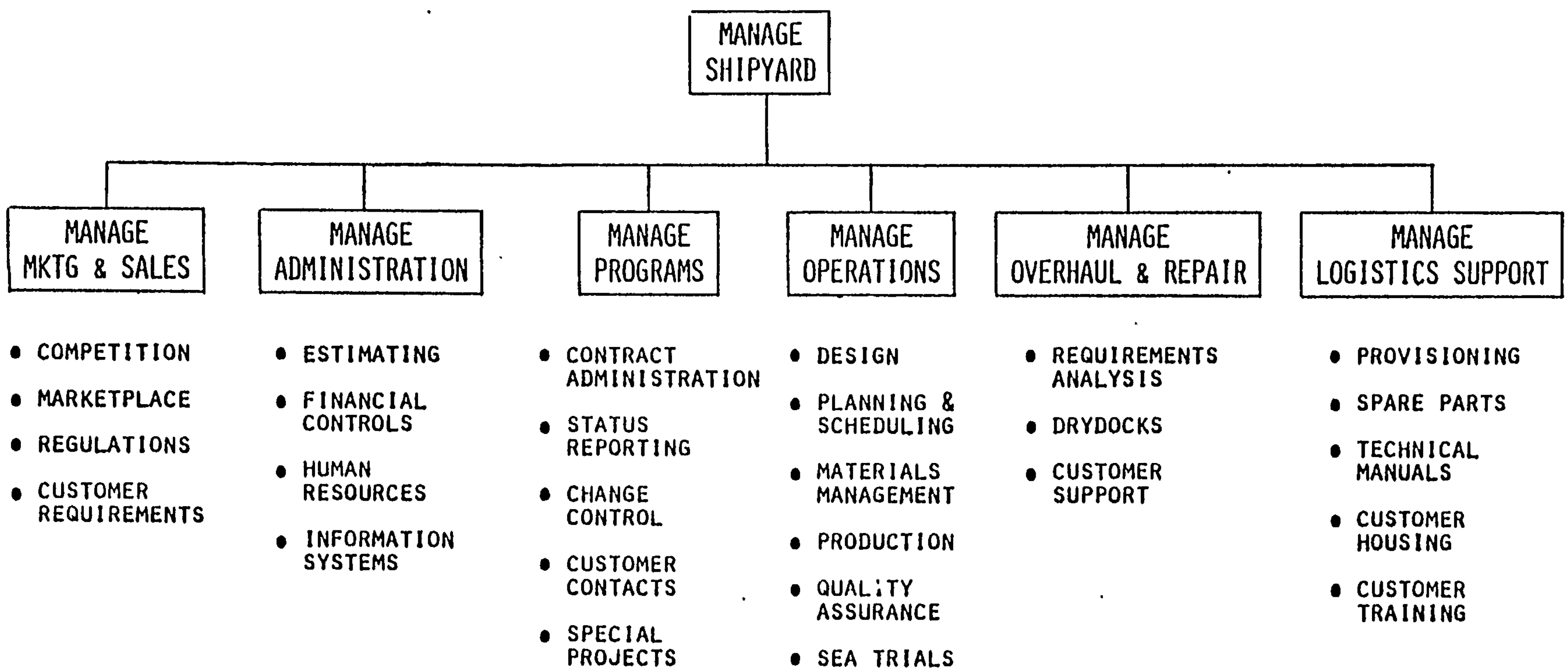
## CIS FRAMEWORK

"WITHOUT SUCH AWARENESS WE WILL CONTINUE TO SUFFER FROM SUBOPTIMAL EFFORTS FROM WELL-INTENTIONED MANAGERS TRYING TO INCORPORATE NEW IDEAS PIECEMEAL FROM THE BOTTOM-UP WITHOUT ANY RECOGNIZED OVERALL FRAMEWORK FOR CHANGE."

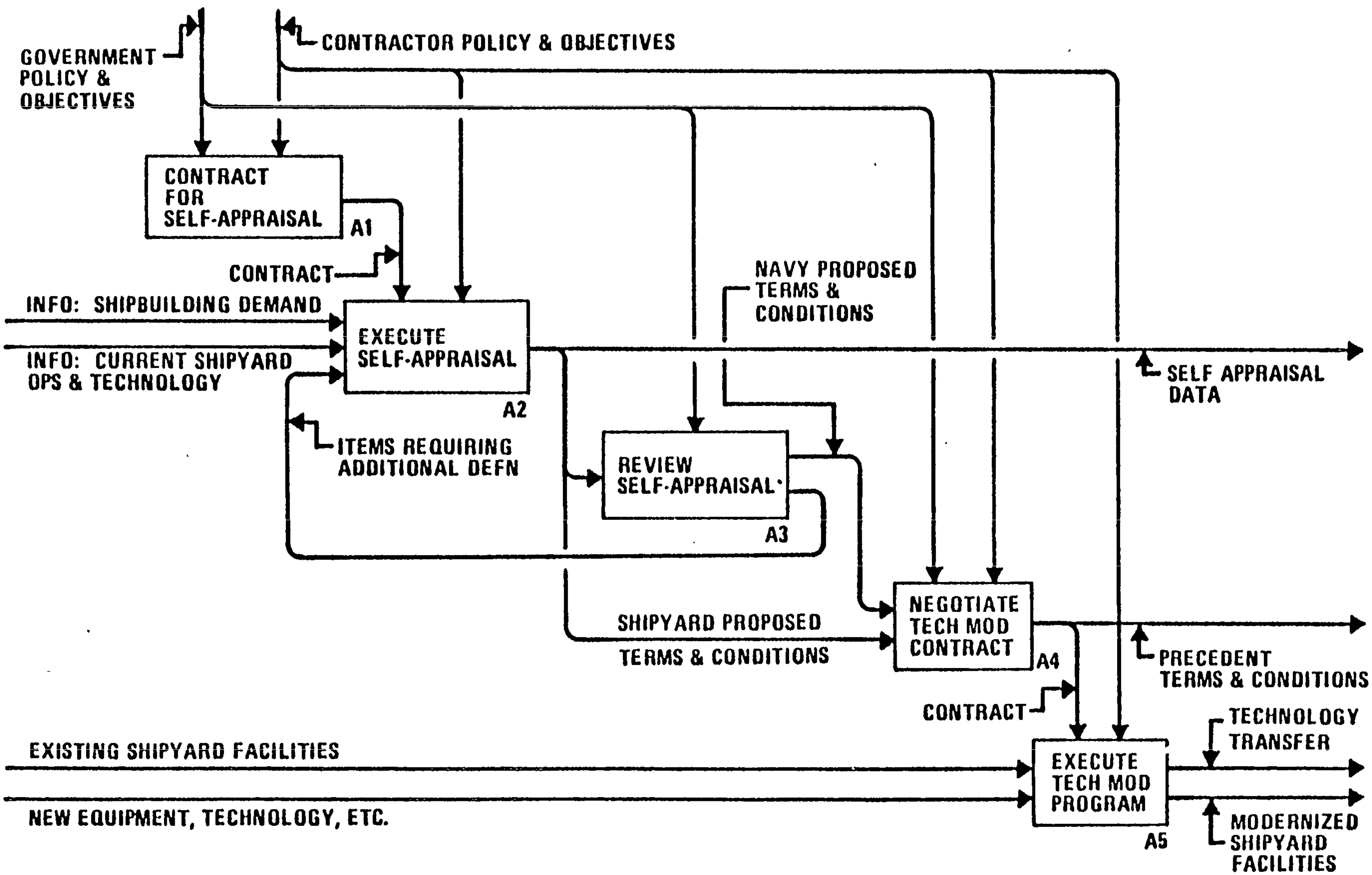
R. VORTMAN

NASSCO

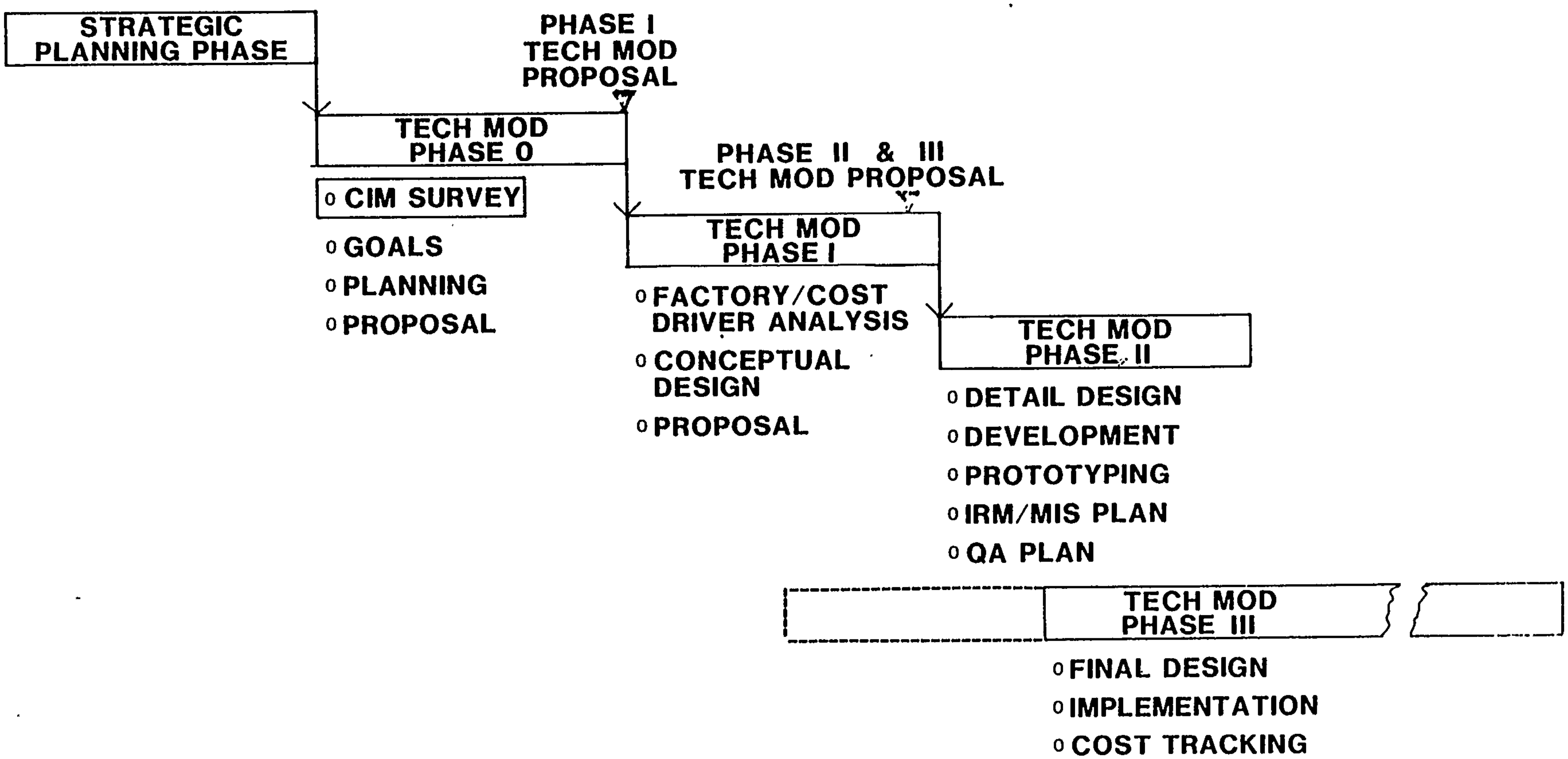
## TASK WORK BREAKDOWN STRUCTURE (TWBS)



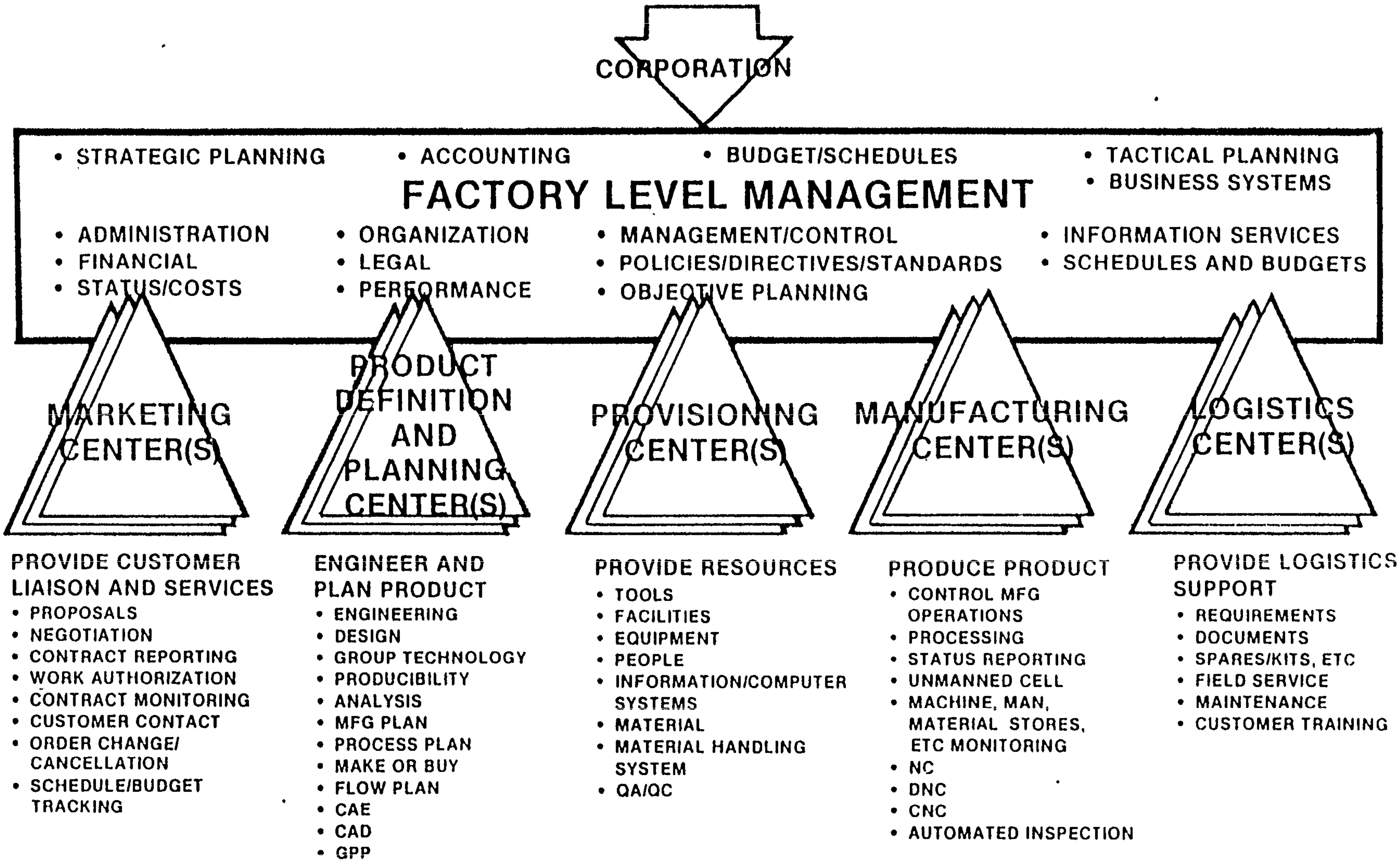
# MANAGE TECHNOLOGY MODERNIZATION



# TECHNOLOGY MODERNIZATION FRAMEWORK



# FACTORY OF THE FUTURE FRAMEWORK

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# PRODUCTIVITY "MYTHS"

- TOUCH LABOR CAUSES THE PROBLEM.

- COMPUTER'S AND PROCESS AUTOMATION WILL SOLVE THE PROBLEM.

- SHORT TERM RESULTS COUNT MOST.

- "FIRST LEVEL MANAGERS" AND "MID-MANAGERS" CAN SOLVE THE PROBLEM <u>WITHIN</u> THEIR AREAS OF ORGANIZATIONAL RESPONSIBILITY.

# LOST PRODUCTIVITY

"AMERICAN WORKERS ACTUALLY ARE PRODUCING, ON AVERAGE, ONLY ABOUT 55% OF THE TIME THEY ARE ON THE JOB. THE RESULTING LOSS TOTALS 350 BILLION DOLLARS ANNUALLY."

T. BARRY & ASSOCIATES

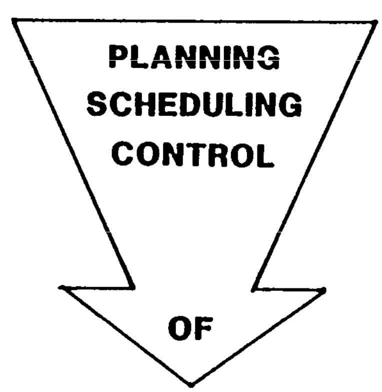
INDUSTRIAL ENGRG-NOV.'80

## 45%
## OF DIRECT LABOR TIME IS NOT PRODUCTIVE

**SOURCE**

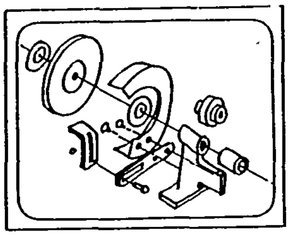
- 35% POOR SCHEDULING
- 25% POOR INSTRUCTIONS
- 15% INFLEXIBILITY
- 25% POOR MATERIAL FLOW

**PAYOFF**

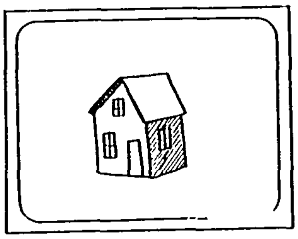



PEOPLE
MATERIALS
FACILITIES

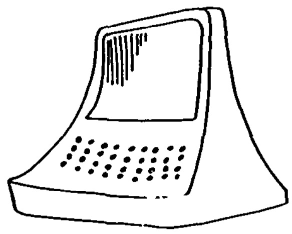
# COMPUTER AIDED DESIGN



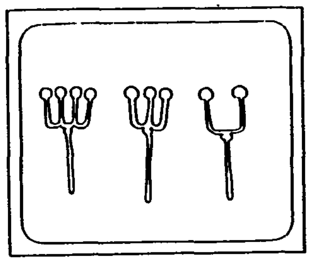
GEOMETRIC MODEL



HOLOGRAPH

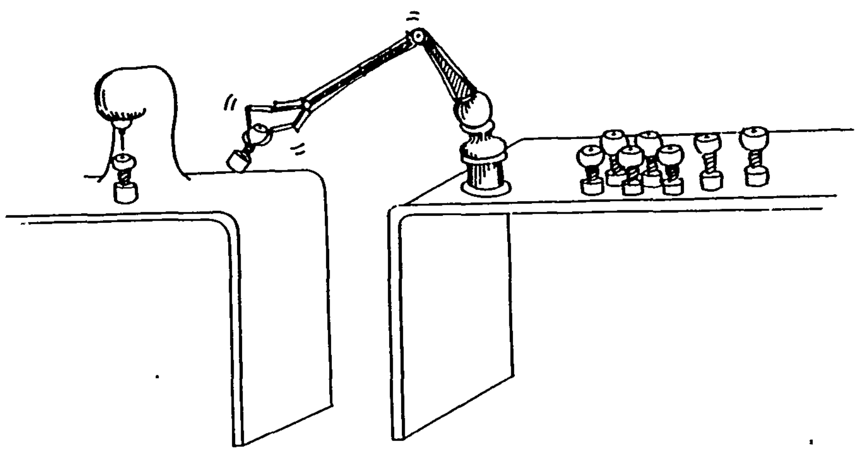


PERSONAL TERMINAL

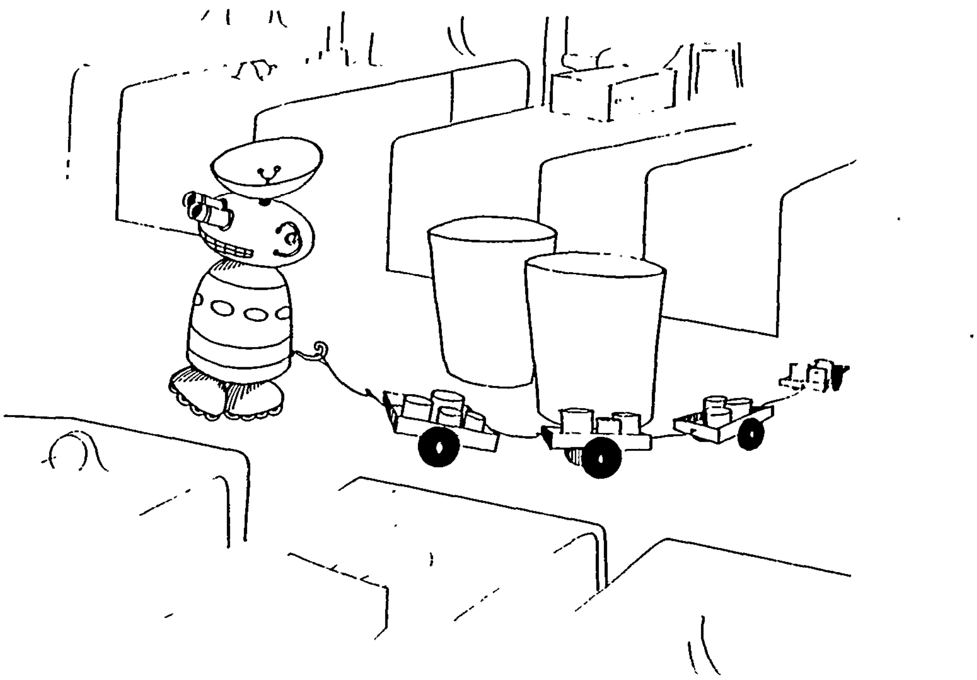


GROUP TECHNOLOGY

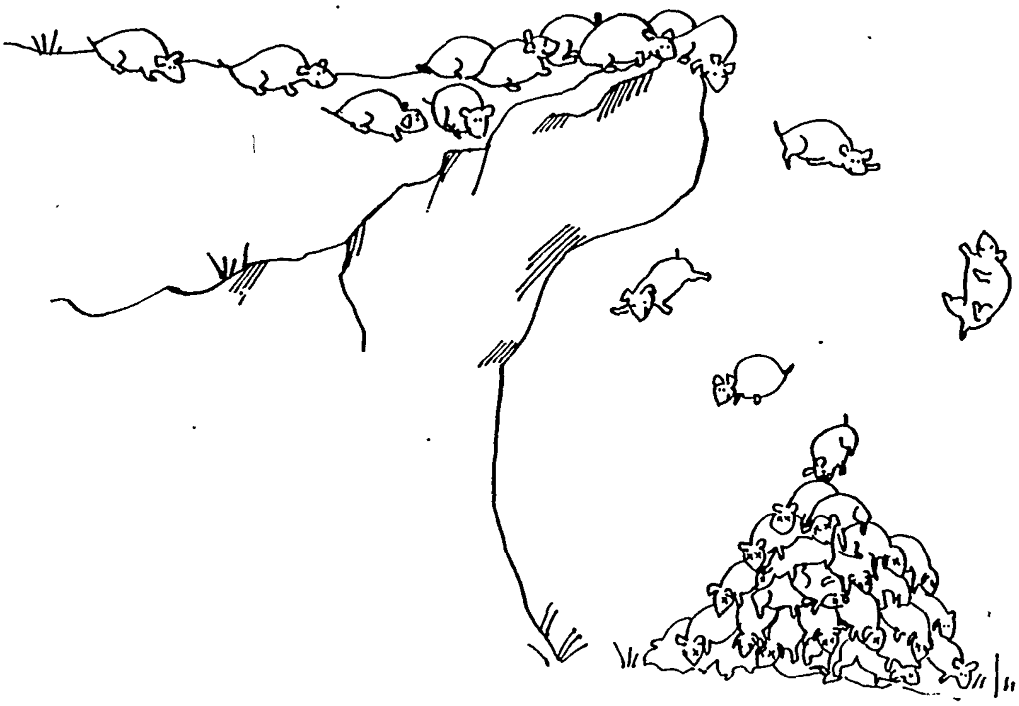
# ROBOTICS



# AUTOMATED MATERIAL HANDLING

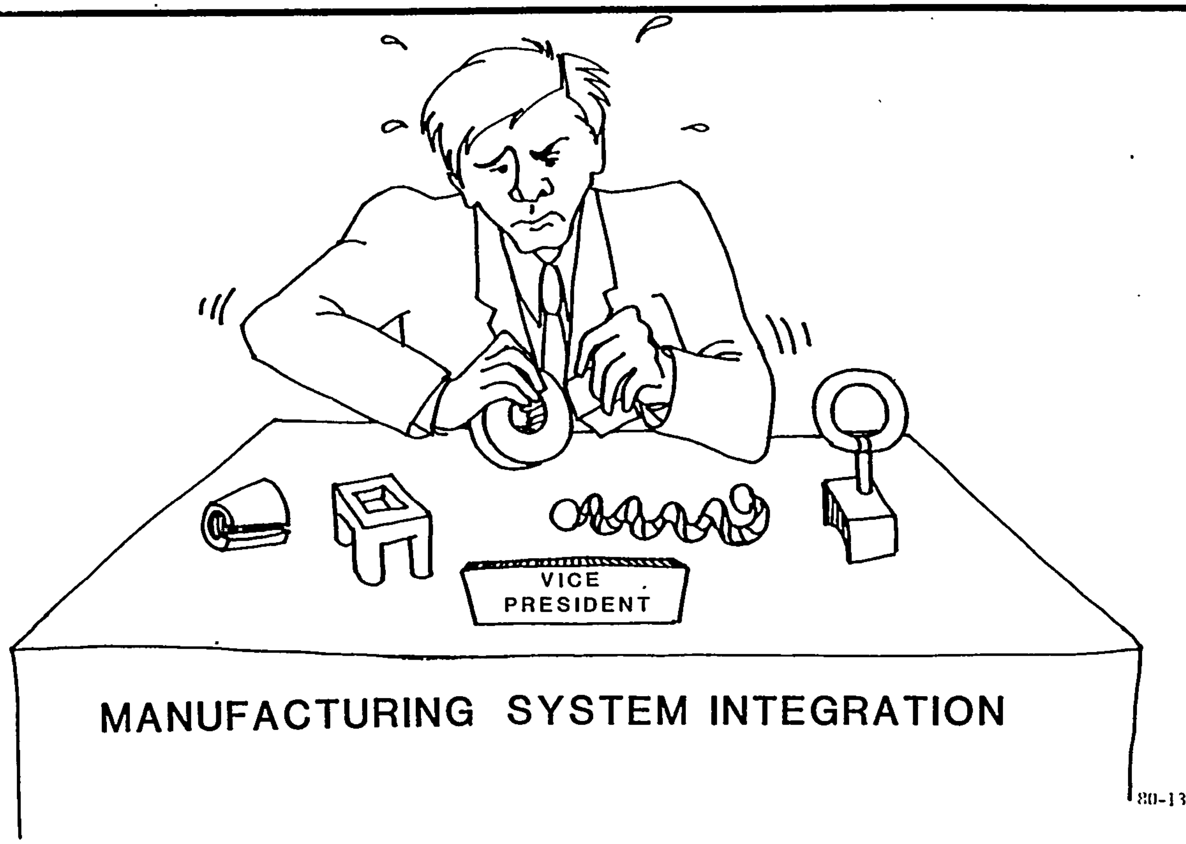


## THE LEMMING APPROACH TO AUTOMATION



80-11

## [C] OMPUTER [I] NTEGRATED [M] ANUFACTURING




## PRODUCTIVITY "DISCOVERIES"

- **ADEQUATE TECHNOLOGY IS AVAILABLE**
- **MANAGERIAL EMPHASIS MUST SHIFT**
- **LONG TERM IMPLEMENTATION STRATEGY REQUIRED**
- **INTEGRATED IMPLEMENTATION IS THE KEY**
- **CONCEPTUAL INTEGRATED SYSTEMS ARCHITECTURE/FRAMEWORK NEEDED FOR PLANNING**
- **[I]NFORMATION [R]ESOURCE [M]ANAGEMENT (IRM) DEPENDENT UPON [C]OMPUTER [B]ASED [I]NFORMATION [S]YSTEM (CBIS) WITH NEUTRAL DATA STRUCTURE**

71 38

## CHANGING THE FOCUS

• EMPHASIZE INTEGRATlON OF MANUFACTURING ACTIVITY VERSUS SPECIALIZATION.

l REFOCUS MANAGEMENT ATTENTION FROM MANUFACTURING TECHNIQUES TO MANUFACTURING SYSTEMS.

• FACE AND RESOLVE NEED FOR MANAGEMENT ORGANIZATION RESTRUCTURING

JIM LARDNER
DEERE&CO.

## INTEGRATED STRATEGIC PLANNING AND IRM

• "ONLY 19% OF THE COMPANIES SURVEYED HAVE INTEGRATED THEIR STRATEGIC PLANNING AND INFORMATION RESOURCE MANAGEMENT (IRM) SYSTEMS"

l "THE COMPANIES THAT DID SO OUTPERFORMED THE REST OF THE SAMPLE BY ABOUT 300% OVER FIVE YEARS ON SUCH MEASURES AS :

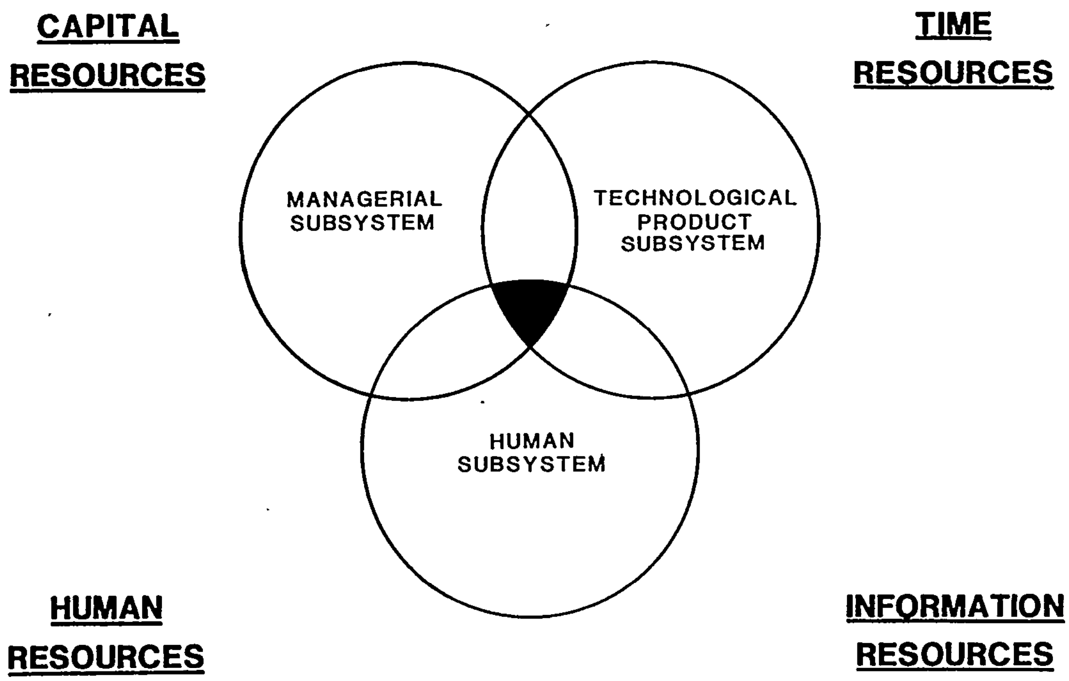
  • AVERAGE RETURN ON EQUITY

  • RETURN ON TOTAL CAPITAL

  l NEW PROFlT MARGINS"

(REF: A.T. KEARNEY. INC, MANAGEMENT CONSULTANT SURVEY OF 40 OF 500 LARGEST U.S. INDUSTRIAL AND FINANCIAL INSTITUTIONS)

# RESOURCE MANAGEMENT

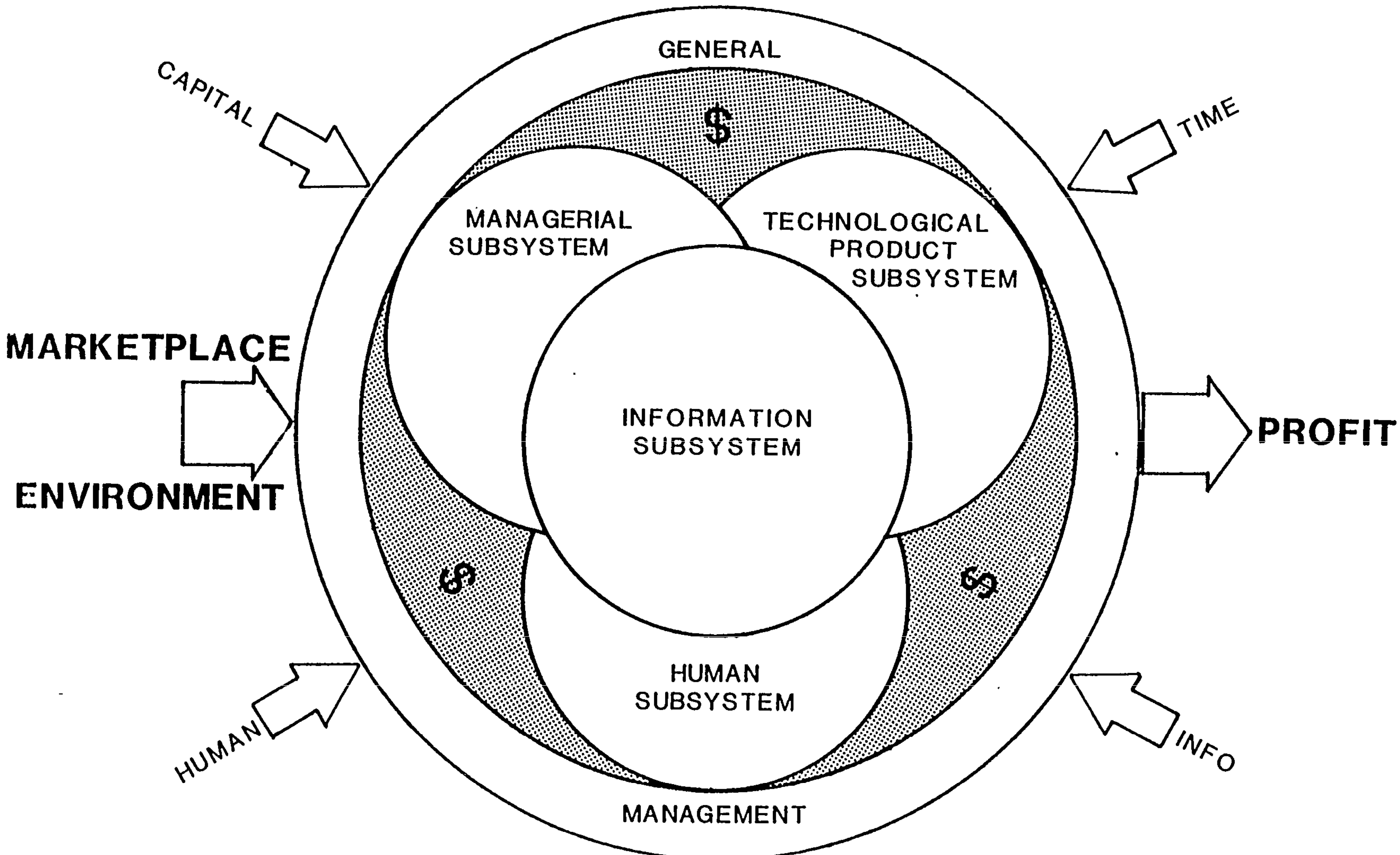



## INFORMATION RESOURCE MANAGEMENT (IRM)

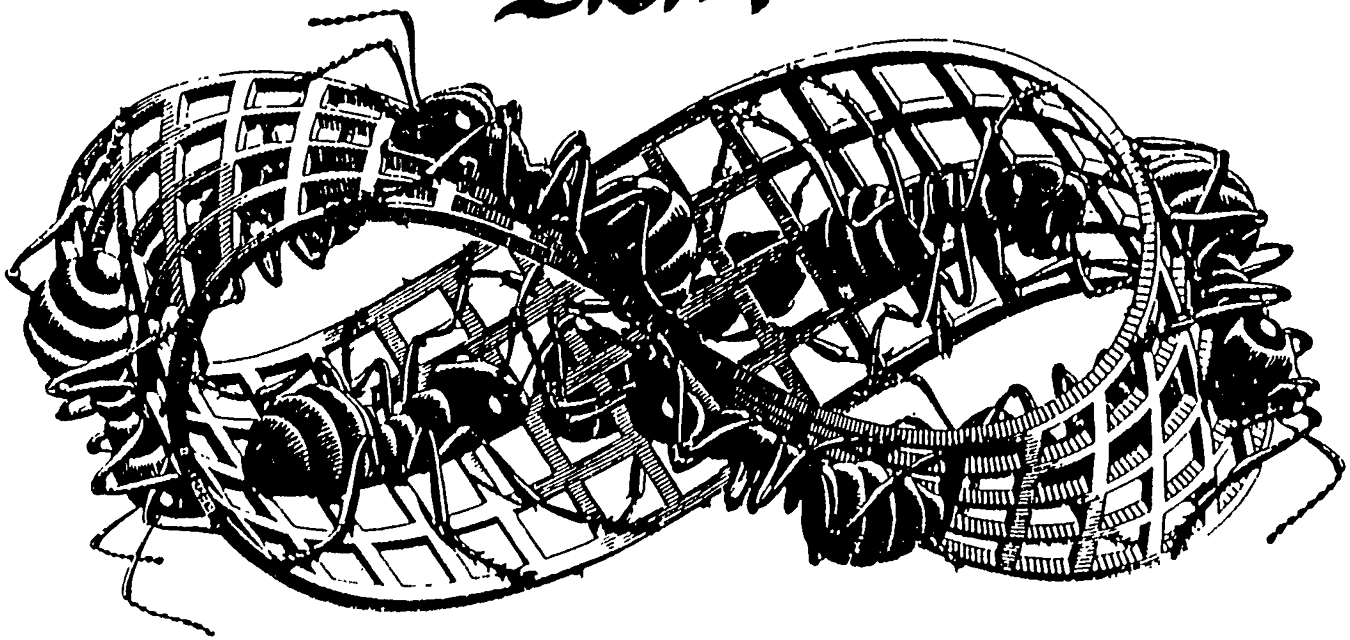
**"INFORMATION IS THE MANAGER'S MAIN TOOL,. INDEED THE MANAGER'S 'CAPITAL", AND IT IS HE WHO MUST DECIDE WHAT INFORMATION HE NEEDS AND HOW TO USE IT."**

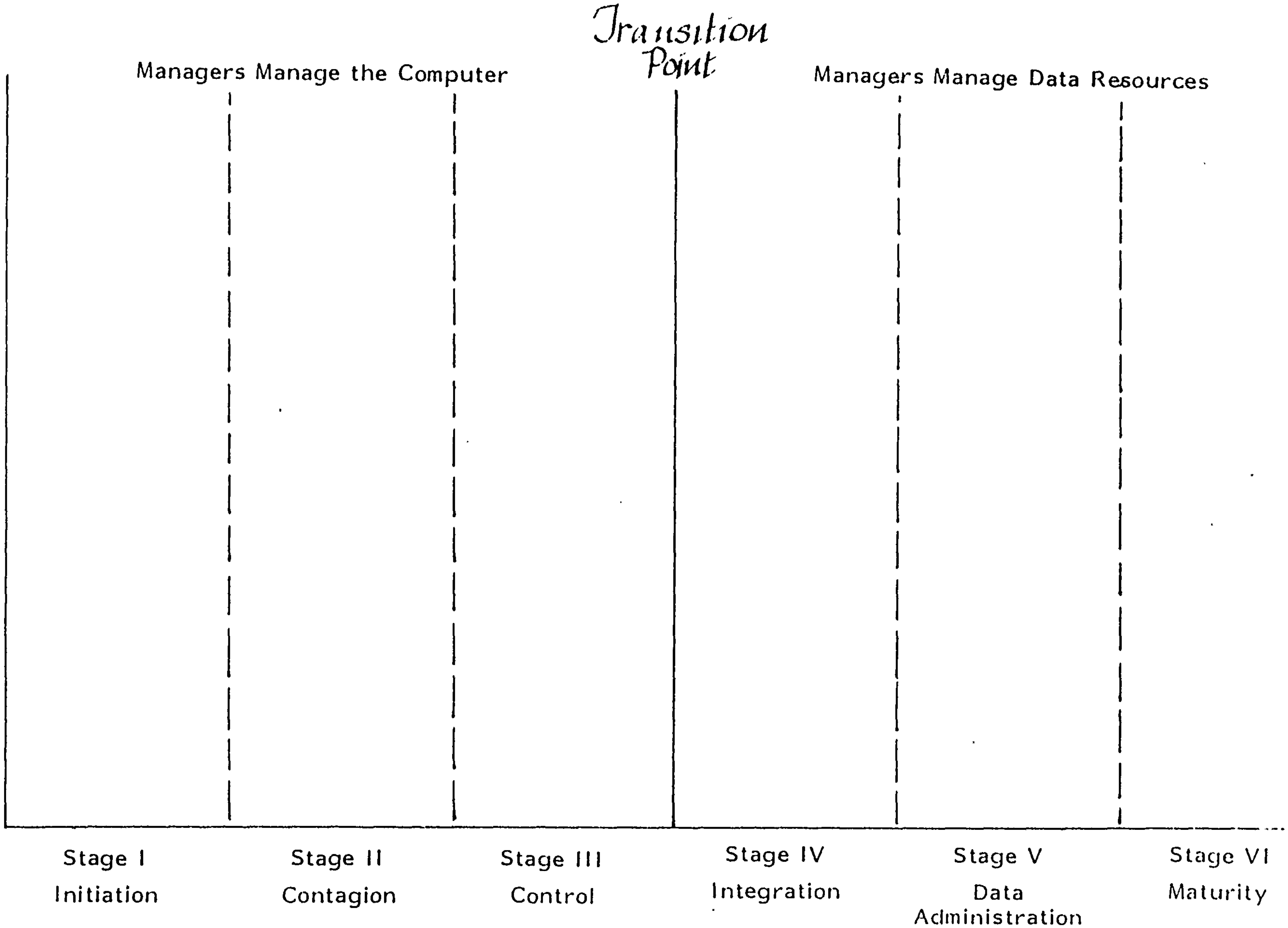
**PETER DRUCKER-"MANAGING THE INFORMATION EXPLOSION'**

# INFORMATION RESOURCE MANAGEMENT



# Managing The Transition From Data Processing to IRM




Transition Point
Managers Manage the Computer
Managers Manage Data Resources
Stage I
Initiation
Stage II
Contagion
Stage III
Control
Stage IV
Integration
Stage V
Data Administration
Stage VI
Maturity

Nolan Scale

## Architecture = Structure Specification

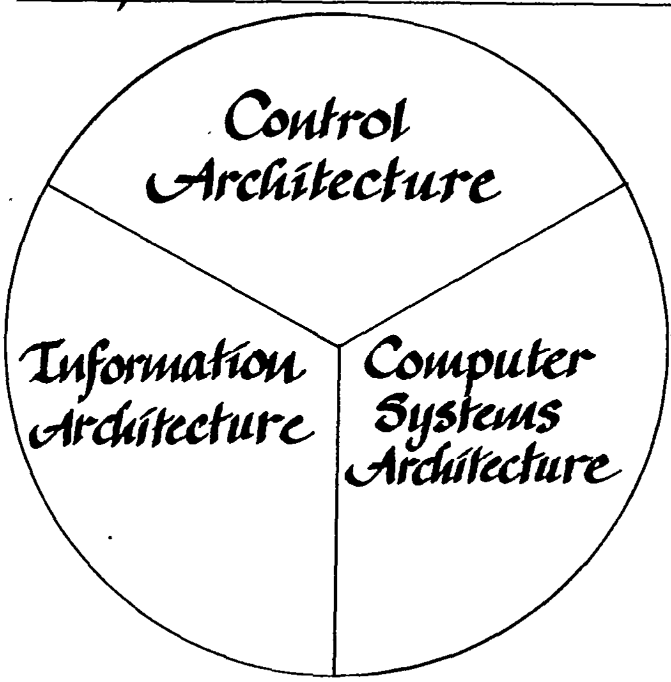
**Specifies:**

- Components
- Logical Relationships
- Uses

**Reflects:**

- Philosophy
- Technique

## Information Resource Component Architectures

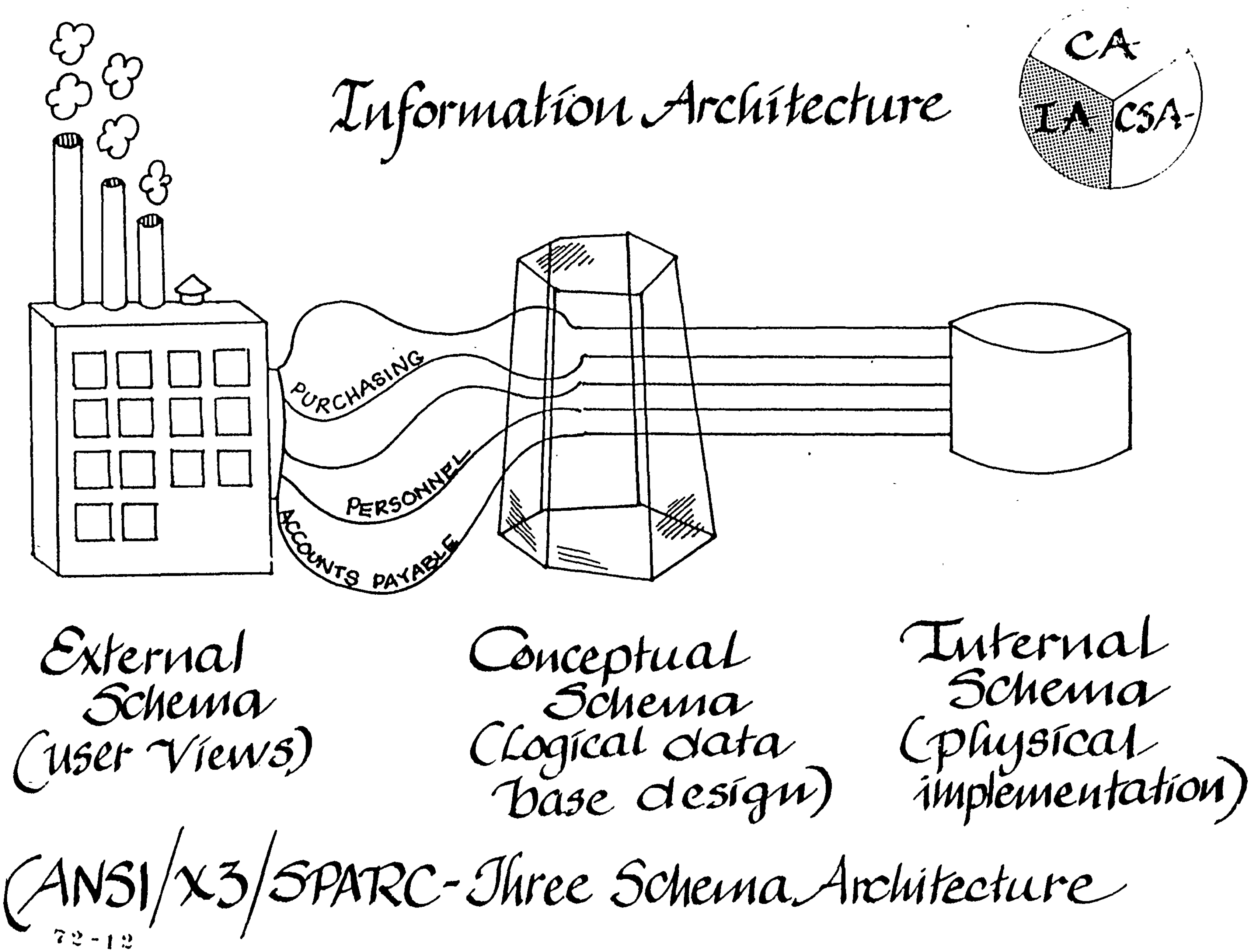


## DATA DRIVEN IRM ARCHITECTURE

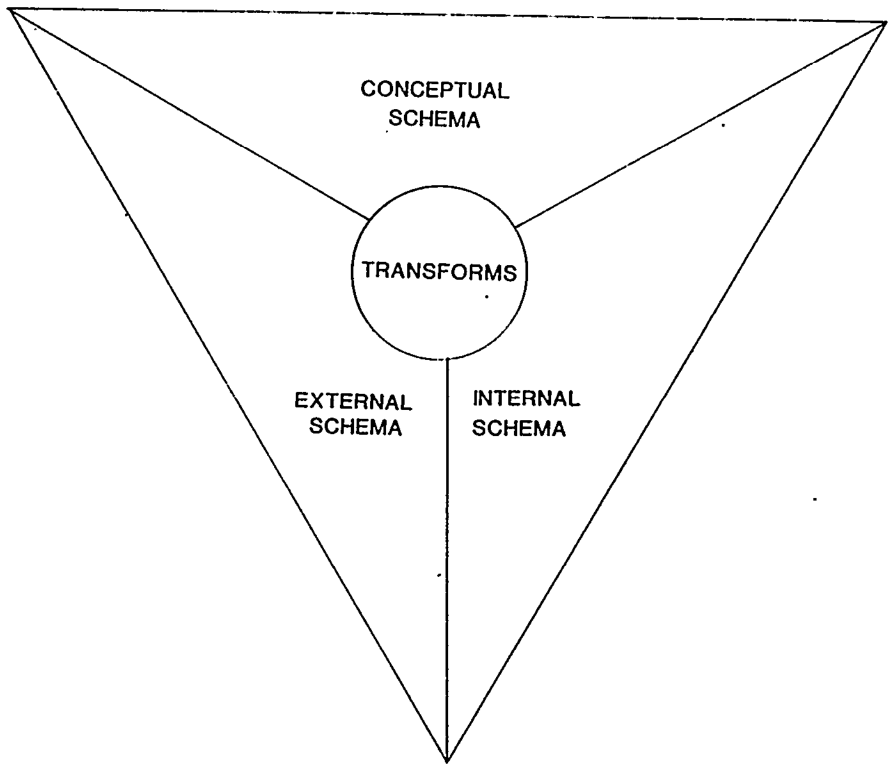
- INFORMATION ARCHITECTURE (IA)
  - DATABASES
  - APPLICATIONS
  - INPUT PROCESSES
  - OUTPUT PROCESSES
- CONTROL ARCHITECTURE (CA)
  - STANDARDS & PROCEDURES
  - SYSTEMS ENGINEERING METHODOLOGY
  - INTEGRATED NEUTRAL DATA STRUCTURE
  - ORGANIZATION & TEAMS
  - PLANS & CONTRACTS

## DATA DRIVEN IRM ARCHITECTURE (CONTINUED)

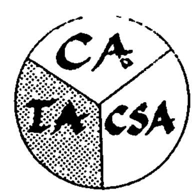
- COMPUTER SYSTEMS ARCHITECTURE (CSA)
  - HARDWARE
  - COMMUNICATIONS
  - SYSTEMS SOFTWARE
  - TOOL KITS

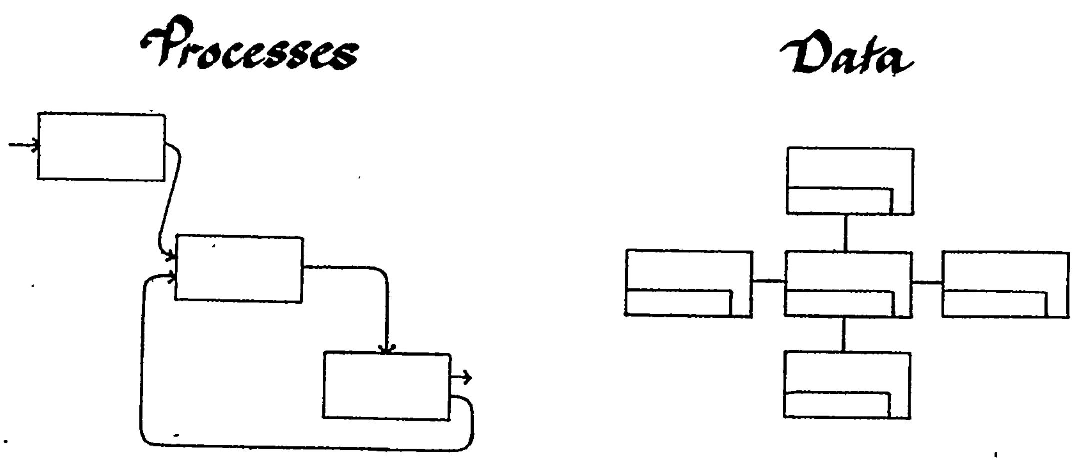

Information Architecture
CA
IA
CSA
PURCHASING
PERSONNEL
ACCOUNTS PAYABLE
External Schema (user Views)
Conceptual Schema (Logical data base design)
Internal Schema (physical implementation)
(ANSI/X3/SPARC - Three Schema Architecture
72-12

## ROSETTA STONE

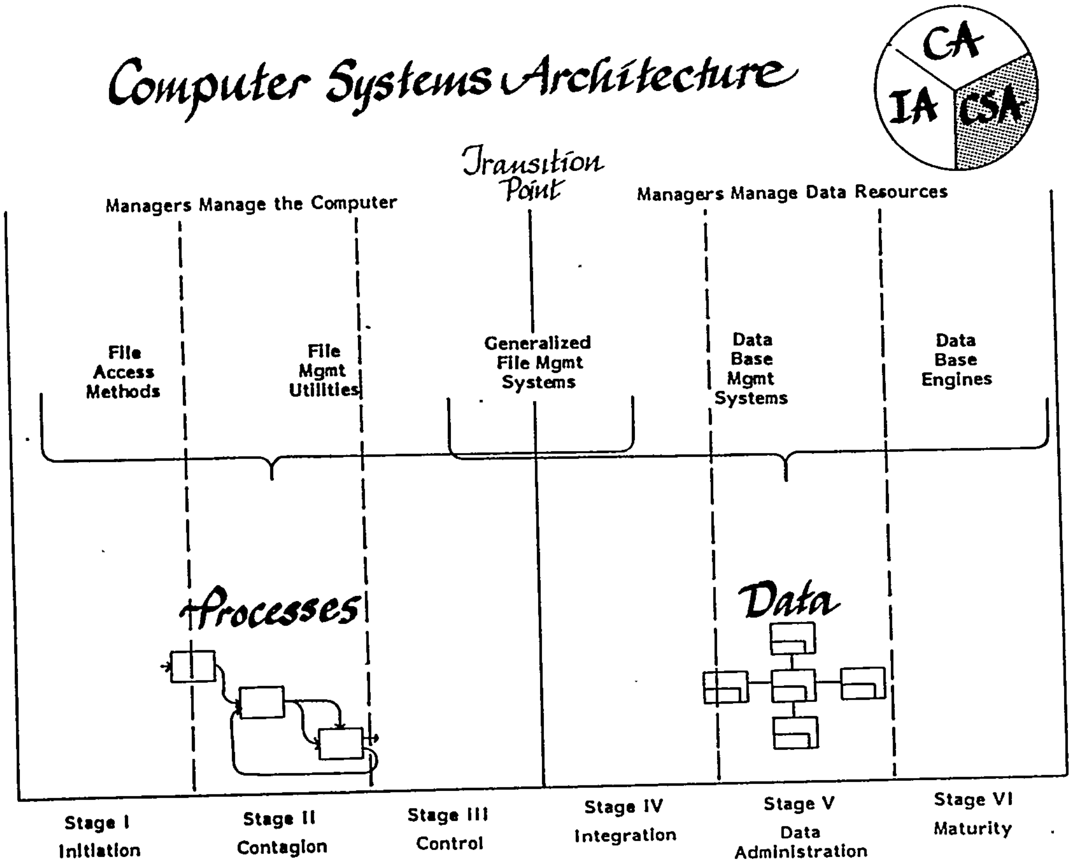



## Information Architecture

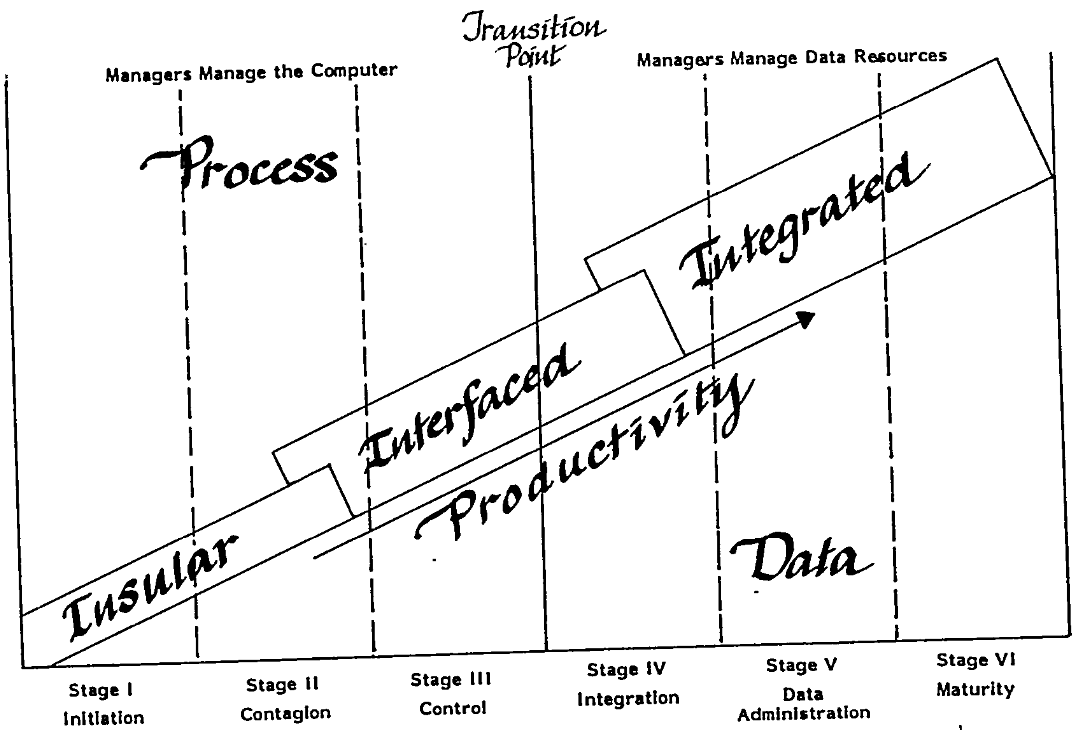


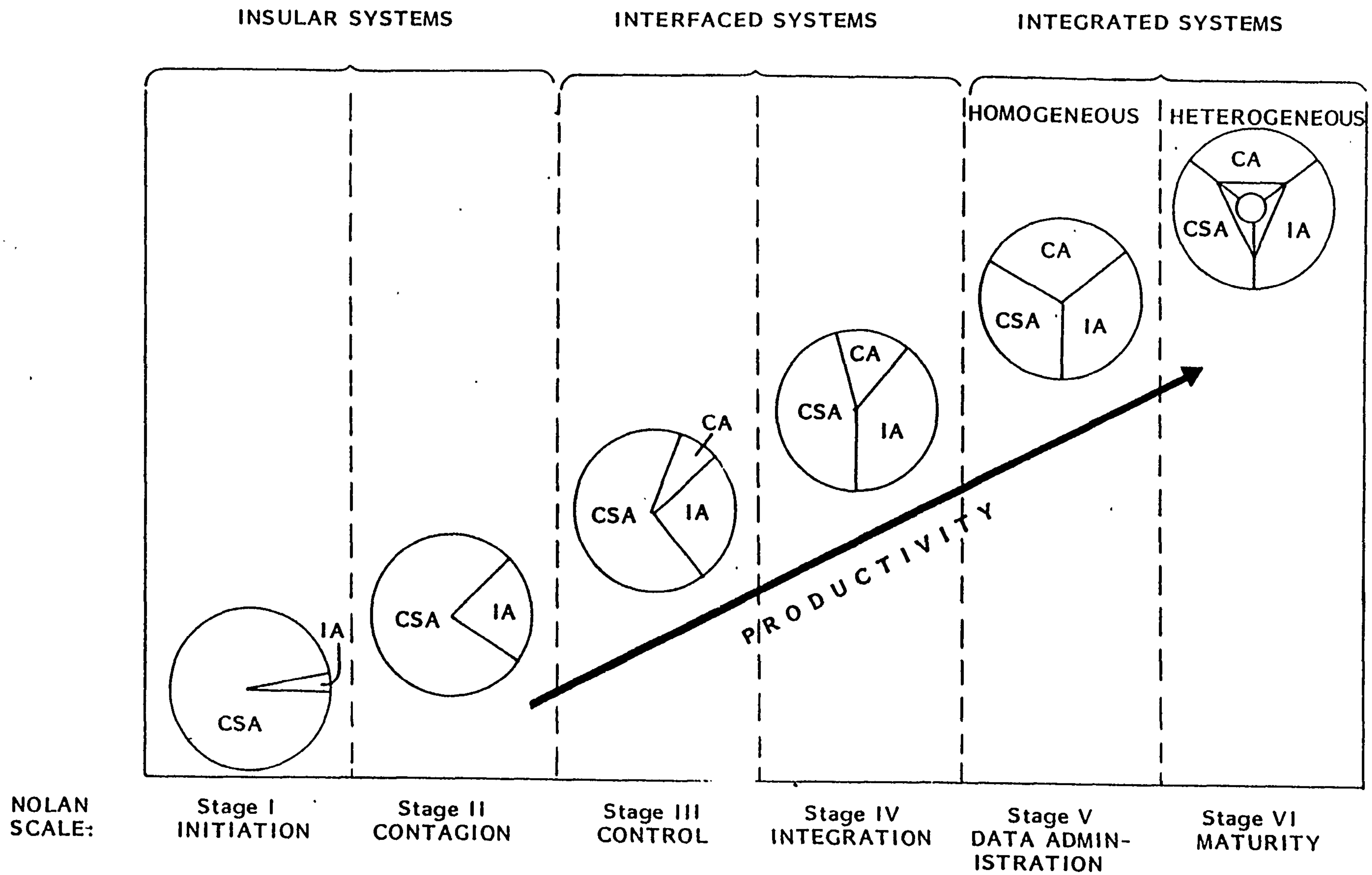
# Computer Systems Architecture




Nolan Scale



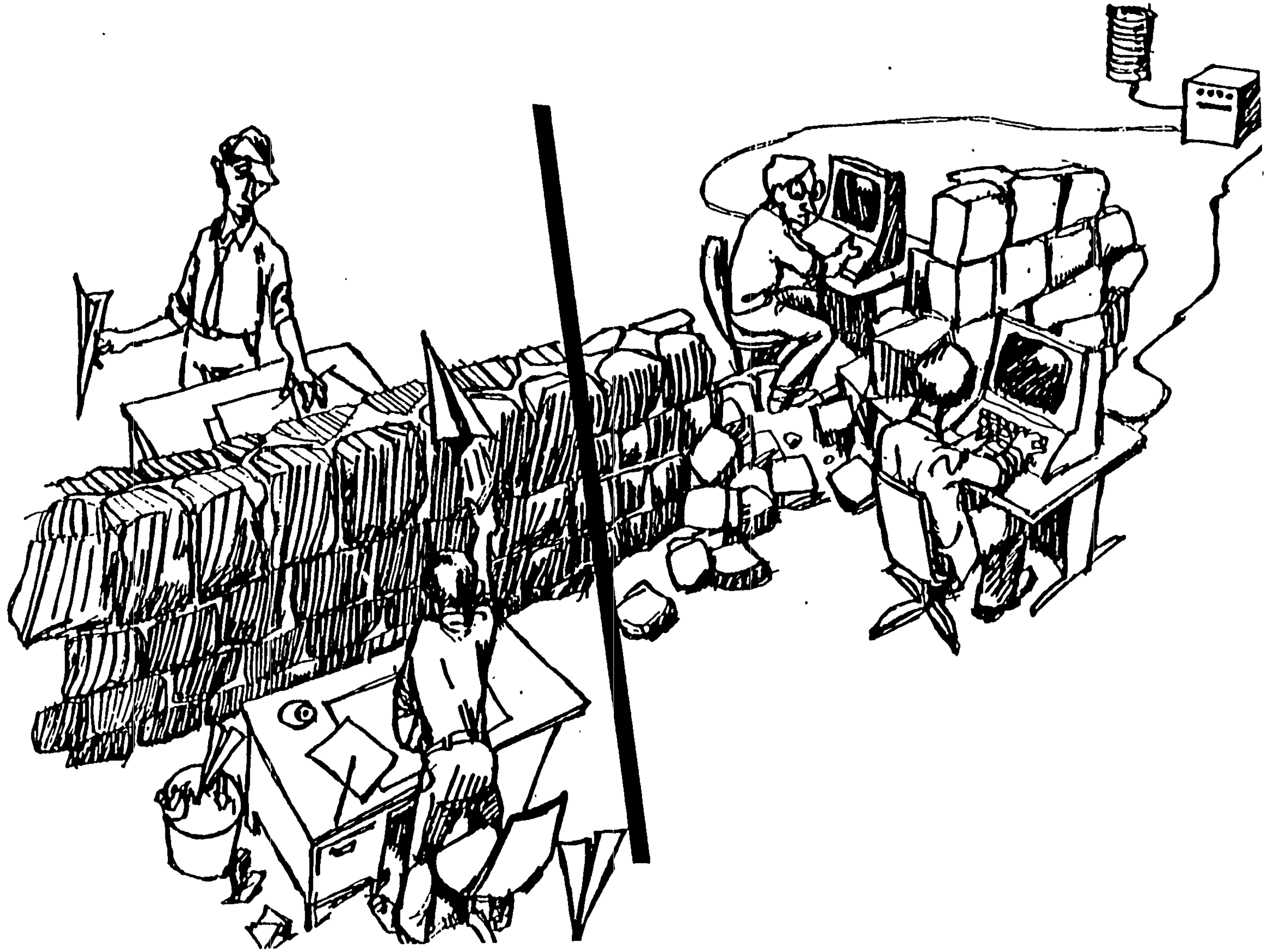

Nolan Scale



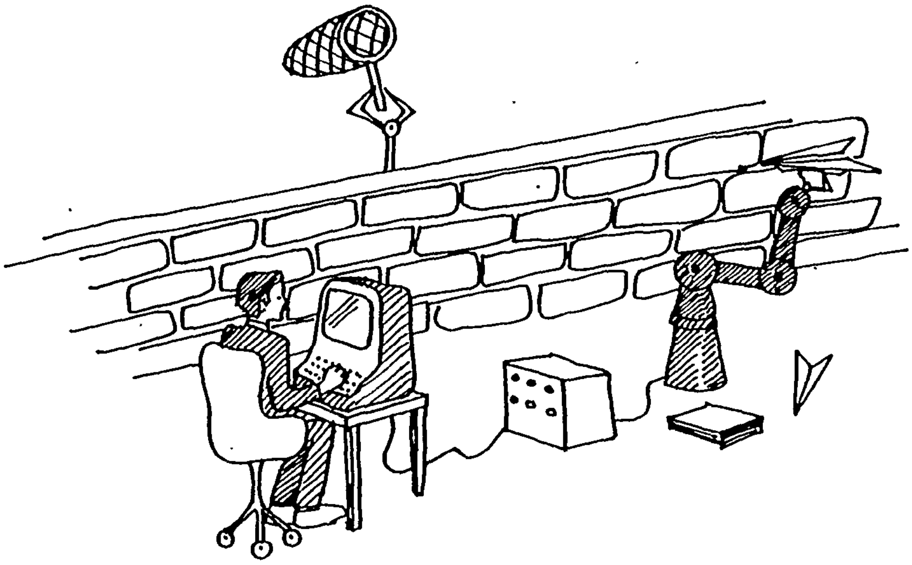

BALANCING THE ARCHITECTURES
AND ACHIEVING INTEGRATION

THE OLD WAY

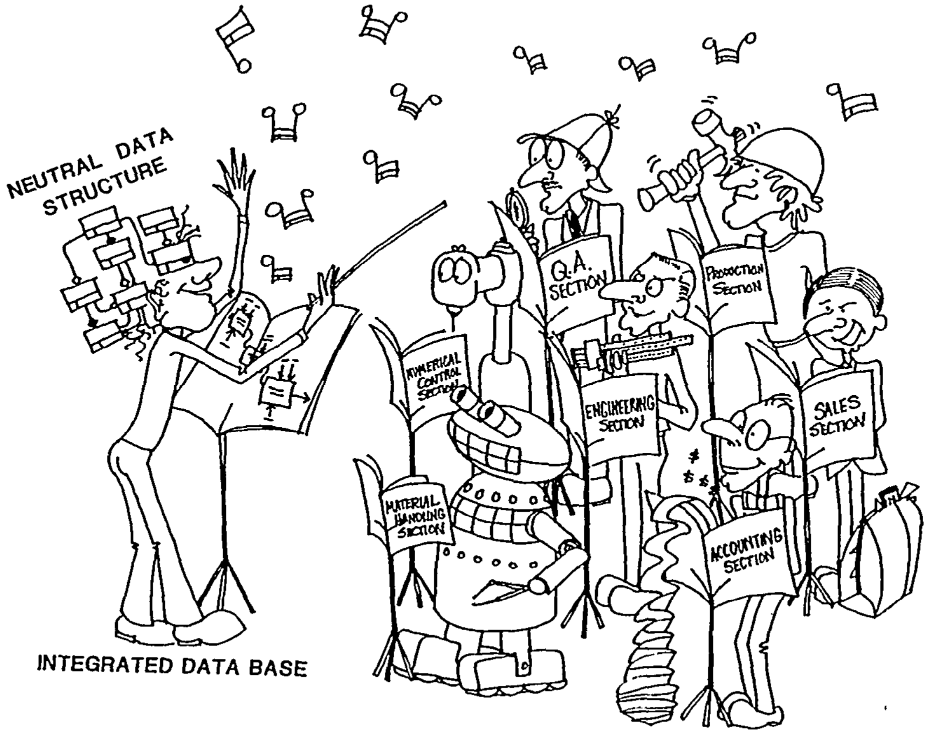
THE NEW WAY



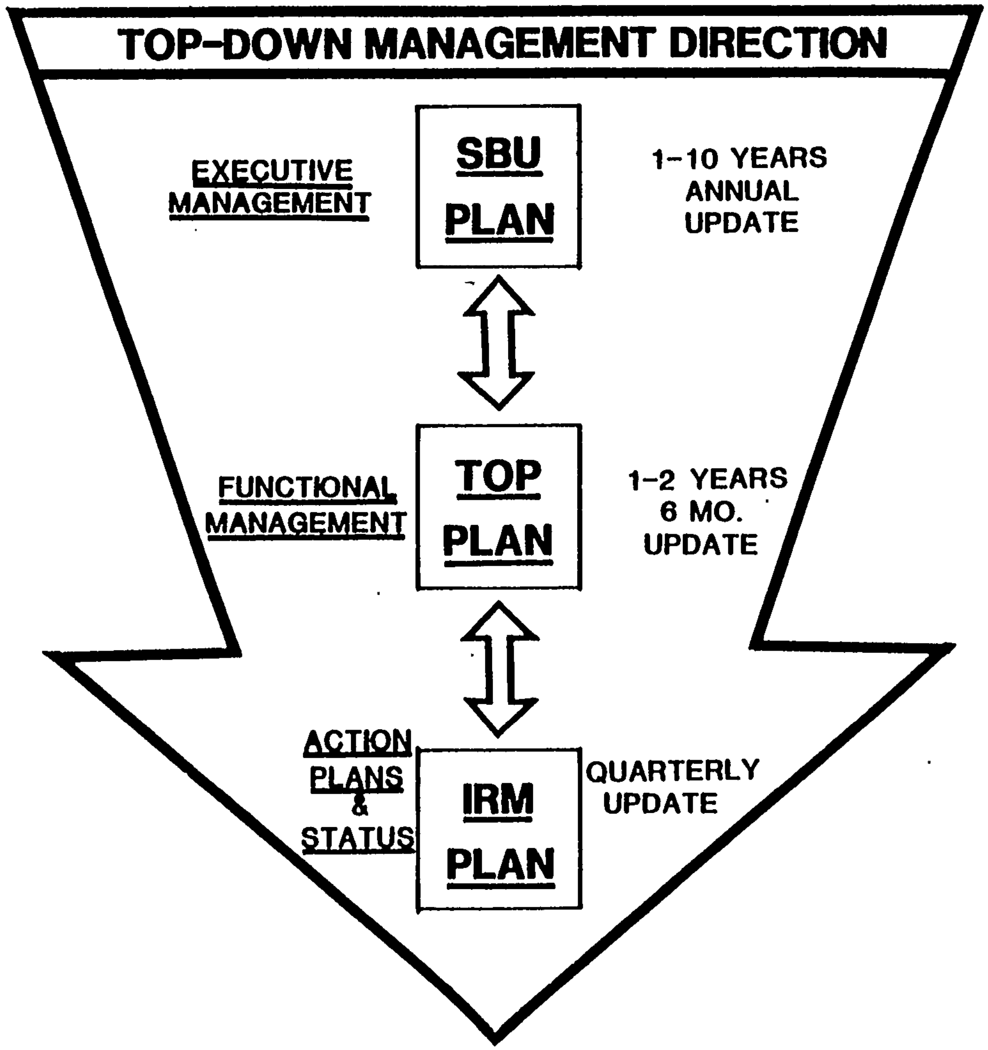
# THE WRONG WAY



## INFORMATION RESOURCE MANAGEMENT (IRM)



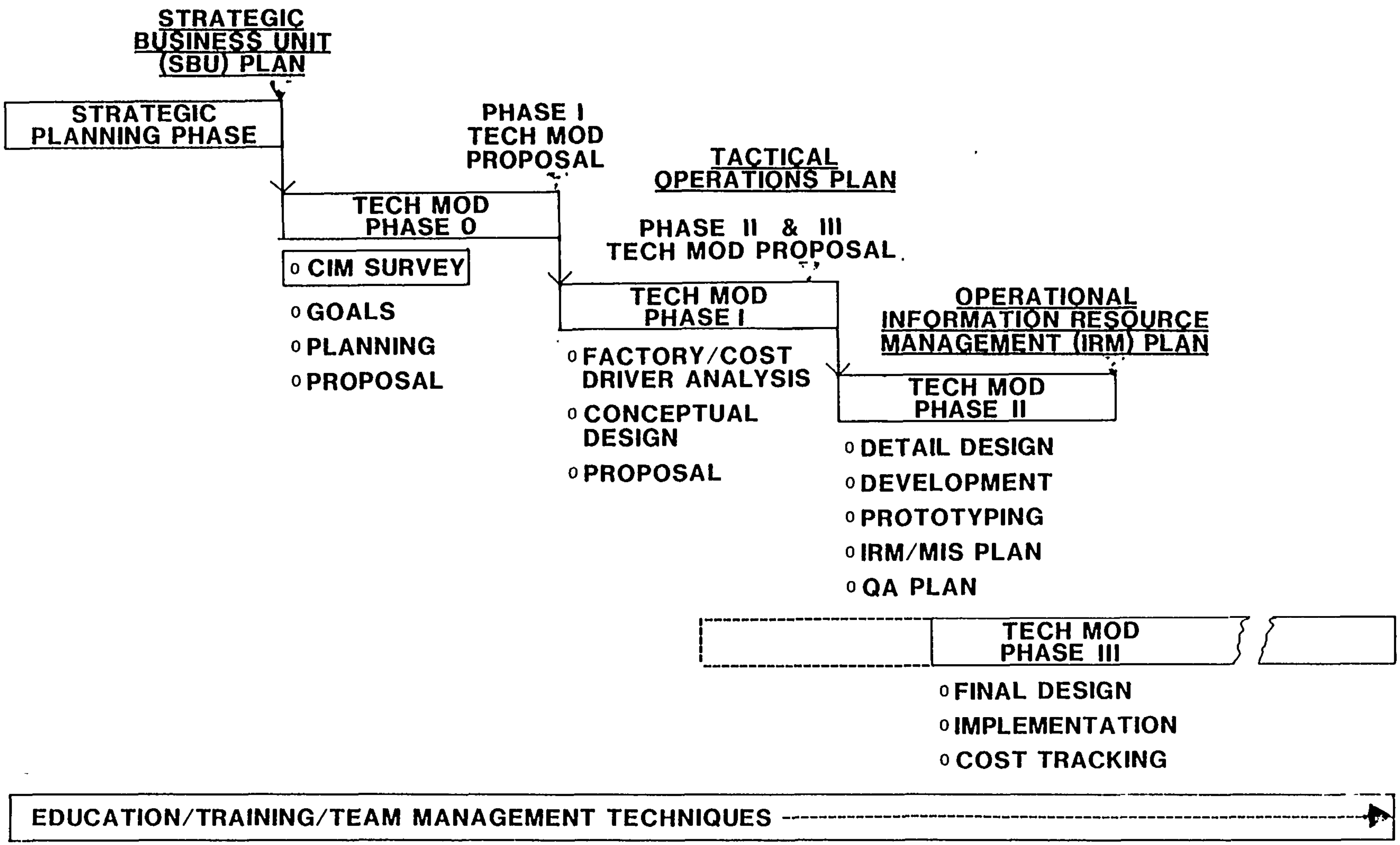
# INFORMATION RESOURCE MANAGEMENT PROGRAM






80-72

# TECHNOLOGY MODERNIZATION FRAMEWORK






80-73

"TOP-DOWN" PROGRAM MANAGEMENT/"BOTTOM-UP" PRO.IECT IMPLEMENTION

# MANAGING CIM FOR TOMORROW

**"IN TURBULENT TIMES, MANAGERS CANNOT ASSUME TOMORROW WILL BE AN EXTENSION OF TODAY. ON THE CONTRARY, THEY MUST MANAGE FOR CHANGE; CHANGE ALIKE AS AN OPPORTUNITY AND A THREAT."**

PETER DRUCKER-"MANAGING IN TURBULENT TIMES"

## C OMPUTER I NTEGRATED S HIPBUILDING

- o COMMON TERMINOLOGY & CONCEPTS
- o PRODUCTIVITY "MYTHS" AND "'DISCOVERIES"
- o CHANGING MANAGEMENT FOCUS
- o INFORMATION RESOURCE MANAGEMENT (IRM)
- o DATA DRIVEN IRM ARCHITECTURE
- o MANAGING CIS FOR TOMORROW

# SHIPBUILDING PROJECT MANAGEMENT

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## ABSTRACT

Uncertainties in material and component delivery as well as fabrication,, assembly, and erection process times make it difficult to effectively use traditional CPM, PERT, and similar methods for shipbuilding project management. A conditional probabilistic project management and control method is proposed which allows incorporation and updating of times and their uncertainties by the use of feedback, to improve real time decision making, project control, and adaptive planning.

## Introduction

American shipbuilding management and planning has become a topic of increasing discussion in recent years and various proposals for change have been advanced. Many of these propose adoption-of certain techniques and approaches successfully used --in other major shipbuilding countries such as Japan and Korea, where shipbuilding management is based on organizational, decision making, and operating structures and procedures founded on quite different cultural backgrounds, human relations, and traditions than those found in the U.S. While some of the techniques and approaches found successful in those countries may be transferrable, it must be recognized that the environment in the U.S. cannot be changed in the short run. This makes successful application of some of these methods difficult.

Factors which make Japanese and Korean shipbuilding competitive include value engineering, quality circles, labor incentives, high productivity manufacturing processes; rationalized ship design and production, effective organization, labor relations and flexibility, good supplier and customer relations, and effective production planning management and control. There are some factors which are distinctly different, such as the lack of adversity between shipbuilder and client on one hand and management and labor on the other hand. There **is** a general recognition and acceptance in these countries that adversary relations and potential litigous actions hinder achievement of ship production efficiency and on schedule low cost (and therefore price) delivery. Similarly most supplier, client, and labor issues with shipbuilding management are resolved by various informal approaches with little if any delay. This is quite different from the generally formal approach used in the U.S.A., where procedure, documentation, and even conflict resolution methods are often defined.

While supplier, subcontractor, and shipyard work performance is highly predictable in foreign shipbuilding countries such as Japan and Korea, U.S. supplier and subcontractor delivery times, as well as shipyard work center performance times are subject to many more uncertainties. There is also a much higher risk that supplies or work delivered are not acceptable or require rework because acceptability checks are usually made only on delivery.

Planning of shipbuilding in the U.S. therefore requires consideration of more significant uncertainties in the performance of the various task activities involved in a shipbuilding project, as well as the consideration of alternative activities,to correct for unexpected development.

## Critique of CPM/PERT Project Planning

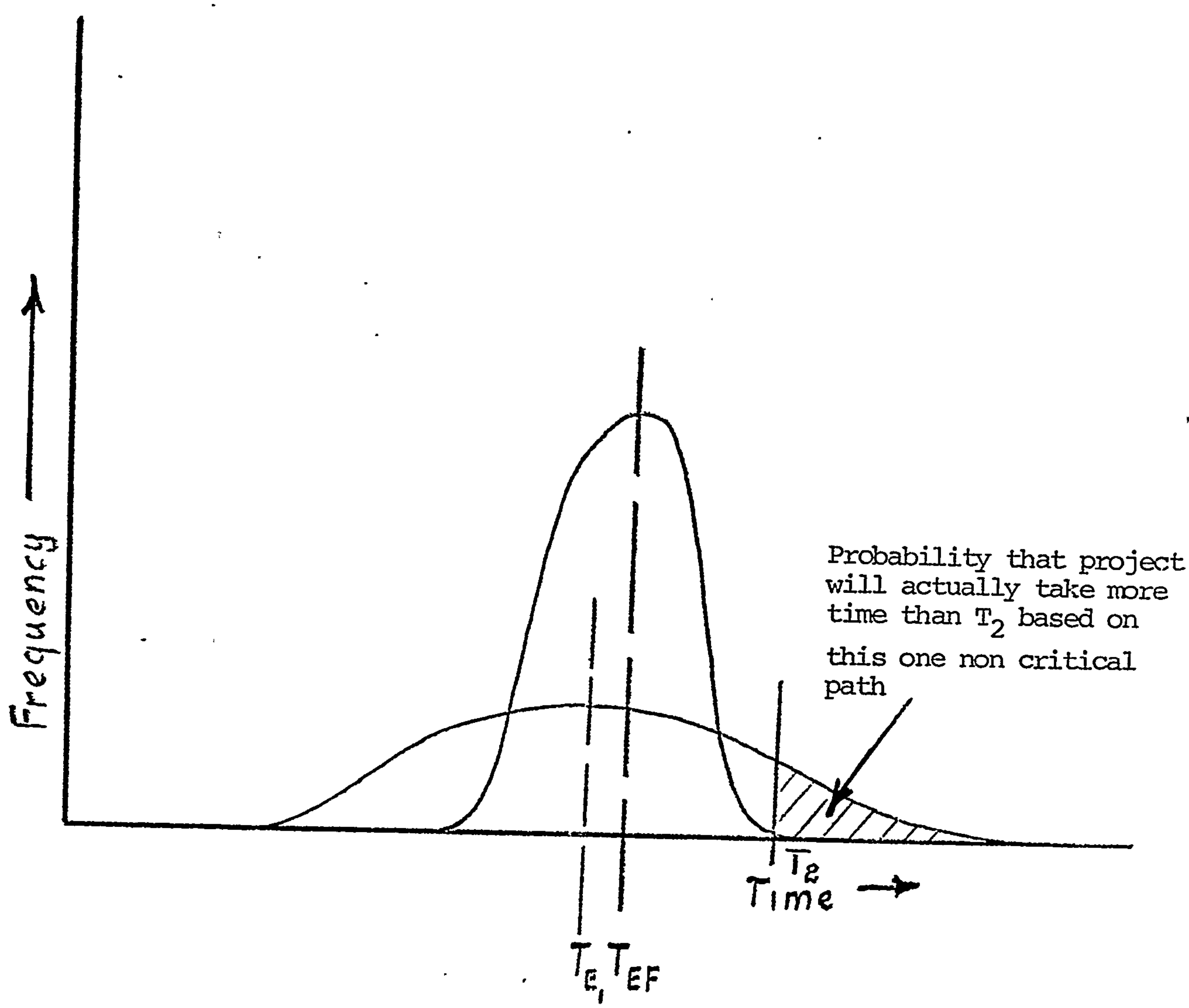
Planning of shipbuilding projects, from planning of complete ship production projects to that of subsystems or block construction, is often performed using either deterministic task and event planning methods such as CPM, or similarly structured probabilistic network planning techniques such as PERT.

-Either or both methods are simply additive networks which allow computation of the expected time and cost of realization of the various events including the completion event. PERT also permits determination of the statistical distribution of time and/or cost of realization of events in terms of the standard deviation of event time and cost. It must be recognized though that these statistical deviations consider only deviations in cost and time of chains of critical activities leading to the event under consideration. In many cases though the event time and cost of critical-activity chain may have a substantially lower deviation than that of non critical activity chains interphasing with the event under consideratior (Figure 1).

The errors introduced by the statistical assumptions of the PERT model (PERT Time, PERT Cost), such as the abovementioned errors in the expected variance of the critical path or path with the largest sum of expected activity times is discussed by Wiest (Ref. 1) l The Beta and Pierson distribution assumption in PERT is ***also*** criticised by Maccrimmon and Ryavez (Ref. 2) as are other statistical shortcomings of the method questioned by authors such as H.O. Hartley and A.W. Wortham (Ref. 3), Dr. J.A. Welsh (Ref. 4) and J. Lukaszewicz (Ref. 5).

The PERT-CPM precedence relationship is extremely rigid since it allows only one interpretation of the timing of activity (i,j) in that event i precedes event j and activity (i,j) must be completed before event j is realized for all activities-interfacing with event j. Furthermore CPM/PERT methods do not permit consideration of alternative activities, feedback, or learning, and consideration of completely alternate project performance structures.

The appropriateness of such a fixed network planning structure has been questioned for R & D projects by researchers such as Eyring (Ref. 6), but the arguments raised are equally valid to applications of PERT/CPM in U.S. shipbuilding which is usually subjected to equally if not larger uncertainties in supply, performance, client demands, and more. One problem not met in the planning of projects in most other industries is frequent delays caused by the unavailability of drawings and plans, which are generally generated while the lead ship is being built.




$T_2$ = Latest time of completion of last activity on critical path

$T_{E_1}$ = Expected time of completion of last activity on non critical path

$T_{EF}$ = Expected time of completion of last activity on critical path - expected completion time of project

FIGURE 1

CPM/PERT COMPLETION TIME DISTRIBUTION

A common occurrence in the use of PERT/CPM is that whenever a serious overrun in time or cost occurs, efforts are made to tighten up on the remaining activities to return the project to planned schedule and budget using the preestablished structure or CPM/PERT network of project performance. A major reason for the problem though may be the structure of the **CPM/PERT** network itself and alternate activity scopes and sequences may offer much better opportunities for performance of the project from this point on. A CPM/PERT network does not allow for alternate network structures to be considered.

While CPM/PERT originated in the U.S. and **PERT** was in fact developed for the specific reason of providing an effective schedule and cost control method for the 'Polaris' program, the most ardent use of the approach to design, plan, and control shipbuilding projects was in Japan starting nearly 20 years ago. For example, the use of an integrated procurement control system based on PERT is credited with the drastic reduction in steel and other storage stock ratios. For example, between 1964 and 1966 the amount of steel stocked in the average Japanese yard as a percentage of the amount of steel supplied to the fabrication shop per month fell from 1.5 to 0.3. In other words from 45 days to 10 days, average demand (Ref. 7). Similar savings were attained not only in the stocking of other materials and components, but also in productivity in design, fabrication, subassembly, assembly, erection, and outfitting. Although U.S. government requirements for use of network procedures have been greatly relaxed or eliminated altogether, **PERT/CPM** appear still to be used in shipbuilding project planning (at least in cost and schedule estimating) and to a lasser degree in shipbuilding project control.

While PERT/CPM are simple methods, with which most shipbuilding managers are familiar, they must recognize the limitations of these methods particularly in the U.S. shipbuilding environment with all its uncertainties, and changes in direction.

Among the reasons for the consideration of different network techniques for shipbuilding project planning and control is that PERT/CPM assumes that each job has a unique, definable beginning and ending and that all other jobs which must be completed before the job can be started are similarly uniquely defined. Similarly all jobs whose starts are triggered by the completion of the job are uniquely defined. The PERT/CPM network describing the shipbuilding project is therefore directed, unidirectional, acyclic, and-does not allow for updating, feedback, or adaption, This unfortunately introduces severe restrictions which make the approach impractical when jobs and their sequence must often be changed, and job or activity performance including the allocation of resources for its performance are conditioned on the performance of other jobs, including jobs which do not interface or are not in sequence with the job or activity under consideration. Yet this is precisely the condition under which shipbuilding projects operate.

## Project Planning Network Developments

Recent developments in network project planning and control methodology concentrated to a large extent on:

1) Incorporation of Resource Scheduling (Ref. 8)
2) Introducing Effect Precedence Methods
3) Consideration of Decision Alternatives in a Network Project Plan
4) Use of Probabilistic Condition of Precedence Sensitive Network Techniques

In resource scheduling we incorporate the use of one or more! resources in the performance of each of the required developments. Precedence methods such as PDM (Procedure Diagram Method) introduce precedence (lead/lag) relationships, eliminate the need for dummy activities, and permit easier changes in the structure of the network, such as the addition or change in sequence of activities. 'Decision Critical Path Methods developed by W. B. Crawston et al (Refs. 9 and 10), allow for the conditional choice among alternative decisions with trade-off of resources used to implement these decisions.

Conditional probabilistic project management and control network techniques permit consideration of-the uncertainties involved in the performance of shipbuilding activities and of alternative activities designed to 'correct for activities which caused time and/or budget distortions. It also incorporates continuous feedback of information to permit reevaluation and updating of the shipbuilding project plan. This method which combines many of the characteristics of the other project planning network techniques was largely developed by A.A.B. Pritsker (Refs. 11 and **12).**

It is generally referred to as GERT (Graphical Evaluation and Review Technique). Detailed description of the method as applied to Queueing-Job-Shop systems are presented in Ref. 13, and a brief summary of the GERT network rationale is given in the Appendix of this paper.

## Proposed Shipbuilding Project Management Method

The method presented here is an application of GERT, by representing shipbuilding projects as **conditional, stochastic networks.** The **shipbuilding process is by its very nature a job-shop queueing system in which most jobs or activities are unique and there is usually a need for some storage of the output of one or a series of jobs before another job or series of jobs can be** performed. While some **jobs are repetitive and others can be** performed by sequential in-line production, most are discontinuous and batch production **or jobs which** if **involved, are usually** of **small**

batch size. Furthermore most jobs performed are stationary and often require a specific facility and location for their performance. As a result we have many work centers which draw upon a pool of resources and perform their activities in prescribed sequences in relation to jobs performed at or by other work centers. In general we can describe the shipbuilding process as a multi-resource constraint activity system with job shop type activities which can be represented as a conditional queueing network.

To represent probabilistic resource constraint job shop type or queueing networks, each job or activity can be defined by the statistical distribution of its resource requirements. GERT networks can be constructed with Exclusive-or, Inclusive-or, and And events or a mixture of different events. Many aggregate project planning models can be designed as Exclusive-o;: network such as a simple ship repair project.

## Ship Repair' Project Management

Assuming that ship repair project management requires the determination of the average utilization of facilities, time to repair and other information, a simple Exclusive-or model may be constructed as shown in Figure **2.** Here we present a greatly simplified tanker repair planning model for a shipyard with one floating and one dry dock, which regularly performs survey repairs on a fleet of tankers-. The network indicates in a very aggregate form some of the major activities and events from the receipt of the ETA to ship departure. Each activity has an associated probability of realization and an equivalent function which represents the statistical distribution of time, cost; etc. required to perform the activity, given the activity is realized. For example, after the receipt of the ETA, there is a probability $P_{12}$ that the ship will actually arrive at the repair port and $P_{1a} =$ $(1-P\ )$ that it is diverted to another port or shipyard, The time from receipt to actual arrival, given the ship arrives, similarly can be expressed by the statistical distribution of time from the receipt of the ETA.

Given the ship arrived, it may be able to proceed to preparation for docking with probability $P_{24}$, may have to be berthed first with probability $P_{23}=(1-P_{24}-P_{2.13})$ or may be prepared for departure again with probability $P_{2.13}$. Once berthed it may have to be unberthed. Given the ship is unberthed it may then proceed to preparation for docking, or departure. Given it is prepared for docking, it may have to wait for an empty dock with probability P44, be docked in the available floating dock with probability P45, or in the available dry dock with probability P46. Again each of these activities has an associated time, cost, etc. distribution. Subsequent activities include shaft and propeller drawing and other jobs until a ship is ready and proceeding for departure again.

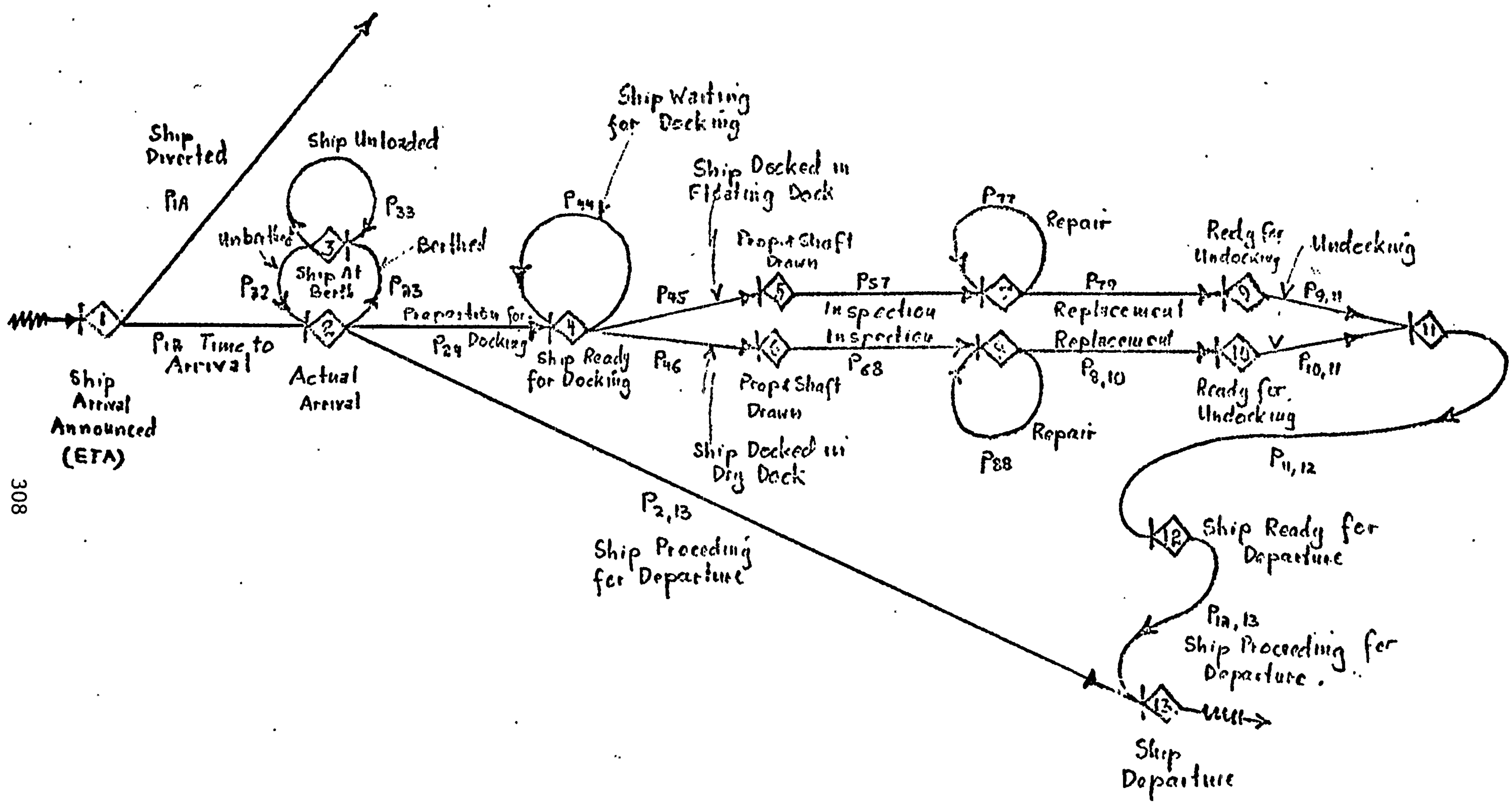



FIG. 2 SHIP REPAIR AGGREGATE PLANNING MODEL

The diagram is usually expressed in matrix form, from which a computational algorithm can readily be formulated. Assuming that the times required for the different activities described by this simplified model each have their particular statistical distribution as obtained from historic data and that the product of the conditional probabilities of realization of the respective activities and their Moment Generating Functions can be expressed in terms of an equivalent function $W_{ij}(s)=P_{ij}MGF_{ij}(S)$, than using Mason's reduction from flowgraph theory we can obtain the equivalent function expressing the relationship between any pair of events or nodes. For example the equivalent function between ship arrival announcement (node 1) and ship departure (node 13)

$$W_{1,13}(s) = W_{1,2}(s)[W'_{2,13}(s) + W''_{2,13}(s)]$$

$$= W_{1,2}(s)\left[\frac{G'_{2,13}(s)\Delta'_{2,13}+G''_{2,13}(s)\Delta''_{2,13}+G'''_{2,13}(s)\Delta'''_{2,13}}{\Delta}\right]$$

where

$G'_{2,13}(s)$ = Path 2-13 via nodes 4, 5, 7, 9, 11, and 12

$$= W_{2,4}(s)W_{4,5}(s)W_{5,7}(s)W_{7,9}(s)W_{9,11}(s)W_{11,12}(s)W_{12,13}(s)$$

$\Delta_{2,13}$ = Path Factor of this Path = $\Delta$ in which all loops touching above nodes are zero

$$= 1-W_{33}(s)-W_{88}(s)+W_{33}(s)W_{88}(s)$$

$G''_{2,13}$ = Path 2-13 via nodes 4, 6, 8, 10, 11, and 12

$$= W_{2,4}(s)W_{4,6}(s)W_{6,8}(s)W_{8,10}(s)W_{10,11}(s)W_{10,12}(s)W_{12,13}(s)$$

and

$$\Delta''_{2,13} = 1-W_{33}(s)-W_{77}(s)+W_{33}(s)W_{77}(s)$$

Finally,

$G'''_{2,13}$ = Path 2-13 direct

$$= W_{2,13}(s)$$

and

$\Delta'''_{2,13}$ = $\Delta$ with all $W_{22}(s) = 0$

where

$\Delta$, the Graph Determinant is

$$\Delta = 1-[W_{33}(s)+W_{22}(s)+W_{44}(s)+W_{77}(s)+W_{88}(s)]$$

$$+[W_{22}(s)W_{44}(s)+W_{22}(s)W_{77}(s)+W_{22}(s)W_{88}(s)$$

$$+W_{33}(s)W_{44}(s)+W_{33}(s)W_{77}(s)+W_{33}(s)W_{88}(s)$$

$$+W_{44}(s)W_{77}(s)+W_{44}(s)W_{77}(s)+W_{44}(s)W_{88}(s)+W_{77}(s)W_{88}(s)]$$

$$-[W_{33}(s)W_{44}(s)W_{77}(s)+W_{33}(s)W_{44}(s)W_{88}(s)+W_{22}(s)W_{44}(s)W_{77}(s)$$

$$+W_{22}(s)W_{44}(s)W_{88}(s)+W_{44}(s)W_{77}(s)W_{88}(s)] + [W_{33}(s)W_{44}(s)W_{77}(s)$$

$$W_{88}(s)+W_{22}(s)W_{44}(s)W_{77}(s)W_{88}(s)]$$

Once the graph determinant is determined the derivation of all kinds of relations within the model becomes easy. For example, average time between arrival of a ship for repair and departure is

$$T(E)_{1,13} = \frac{\partial W_{1,13}(s)}{\partial s}\Big|_{s=0}$$

Probability that an arriving ship will be repaired in the floating dock

$$P_{4,11} = W_{4,11}(s)/[W'_{2,13}(s)+W_{2,13}''(s)]\Big|_{s=0}$$

We could similarly find the probability that an arriving ship will require shaft or propeller repair while being docked in the floating dock, or the average time a ship requires in port for (survey) repairs given it has to discharge cargo in the port as well, or we may want to compute the probability that a ship has to wait in excess of say 3 days before a specific dock is available, given it had to be unloaded before preparation for docking. A real world planning problem of this type would obviously have many more activities and events, with each activity expressed by its conditional probability of realization or use as well as the statistical distribution of its resource requirements, given it is used.

Analysis of larger, real world models is obviously done using computers. The model is then developed as a matrix in which each square contains either a zero or the product of the conditional probability that the activity is realized and the Moment Generating function of the statical distribution of the resource requirements. Table 1 is a listing of distributions acceptable to such a GERT program. A GERT project planning model can also be used to determine the sensitivity of a project outcome or performance to changes in the probability or resource requirements of one or more activities which form part of the project.

TABLE 1

DISTRIBUTIONS ACCEPTABLE TO GERT PROGRAM

| Type of Distribution | $M_E(s)$ | Mean | Second Moment | Input Variables |
|---|---|---|---|---|
| Binomial (B) | $(pe^s+1-p)^n$ | $np$ | $np(np+1-p)$ | $w_E(o);n,p$ |
| Discrete (D) | $\frac{p_1e^{st_1}+p_2e^{st_2}+\ldots}{p_1+p_2+\ldots}$ | $\frac{p_1T_1+p_2T_2+\ldots}{p_1+p_2+\ldots}$ | $\frac{p_1T_1^2+p_2T_2^2+\ldots}{p_1+p_2+\ldots}$ | $w_E(o);p_1,T_1,p_2,T_2;$ |
| Exponential (E) | $(1 - s/a)^{-1}$ | $1/a$ | $2/a^2$ | $w_E(o);\ 1/a$ |
| Gamma (GA) | $(1 - s/a)^{-b}$ | $b/a$ | $\frac{b(b+1)}{a^2}$ | $w_E(o);1/a,b$ |
| Geometric (GE) | $\frac{pe^s}{1-e^s+pe^s}$ | $1/p$ | $\frac{2-p}{p^2}$ | $w_E(o);p$ |
| Negative Binomial (NB) | $\left(\frac{p}{1-e^s+pe^s}\right)^r$ | $\frac{r(1-p)}{p}$ | $\frac{r(1-p)(1+r-rp)}{p^2}$ | $w_E(o);r,p$ |
| Normal (NØ) | $e^{(sm+\frac{1}{2}s^2\sigma^2)}$ | $m$ | $m^2 + \sigma^2$ | $w_E(o);m,\sigma$ |
| Poisson (P) | $e^{\lambda(e^s-1)}$ | $\lambda$ | $\lambda(1+\lambda)$ | $w_E(o);\lambda$ |
| Uniform (U) | $\frac{e^{sa}-e^{sb}}{(a-b)s}$ | $\frac{a+b}{2}$ | $\frac{a^2+ab+b^2}{3}$ | $w_E(o);a,b$ |

Similarly we can determine the variance and other statistical measures of the time or other resource use for the whole project or any subnetwork of activities relating any set of two events or nodes. GERT networks similarly permit multiple inputs and outputs and multiple feedback loops which can be used to simulate repetitive performance of activities.

## GERT Simulation in Shipbuilding Project Management

A basic GERT Exclusive-or or similarly structured network model, as discussed, is useful for the analysis of aggregate or small-scale shipbuilding planning problems. When the number of activities becomes large and when the network representing the project and its alternatives is represented by a large resource constrained queueing network, then a simulation approach is usually the only effective approach. GERT Simulation or GERTS was developed by Pritsker (Ref. 13) and later expanded by Hogg, Phillips, Maggard, and Lesso (Ref. 17 and 18). Cochran and Rowe studied the sources of disruption to project cost and delivery performance (Ref. 15) while Cochran added the impact of design uncertainty and delivery urgency in a later paper (Ref. 16). A shipbuilding project was used by Wolfe, Cochran, and Thompson as an example for a GERTS-based interactive computer system for analyzing project networks incorporating improvement curve concepts (Ref. 14).

Since then several applications of GERTS to manufacturing, including shipbuilding project planning, have been made. The results have shown the great advantage of this approach as compared to the use of CPM/PERT, Precedence Diagram and other project network planning methods. A number of extensions to GERTS have been developed in recent years. These are found in GERTS III, GERTS III Q, GERTS III C, and **GERTS III** R {where Q, C, R stand for Queue, Cost, Resource, etc.) There are also versions of GERTS (Fortran) which combine Q and R consideration.

To model a shipbuilding project we prepare a network diagram representing the structure of activities and events comprising or judged necessary for the performance of the project. Alternative activities (not necessarily leading to the same event) which may be introduced to use alternate processes, make more effective use of resources; or for other reasons, are next Identified. We similarly define the number of 'incoming activities required to realize a node or event for the first time, as well as the number of completed incoming activities required to realize it even after the first time. For example position one events on a flat panel line may require five edge prepared plates to be positioned. Next queue disciplines, at the start of the various activities at which queueing is allowed, must be defined.

To control resource use, resource levels and resource use costs are set for each activity and resource allocation rules are determined. GERTS simulation programs define six node types:

Source, Statistics, Mark, Queue, ***Sink,*** and Standard. Some versions (Ref. 15) include storage, generator, and distinguisher nodes. (For description of GERT node characteristics see Appendix.) The basic GERTS programs require each unit in a queue to require the same storage. Wolfe, Cochran, and Thompson (Ref. 14) recognized that this may be unrealistic in ship production analysis, and therefore introduced a storage node, which permits the amount of space required before or by an activity to be specified in terms 0'- area, volume, weight, etc. In GERTS, when storage or queue capacity is exhausted blocking occurs, yet resource utilization may, In part, continue at the blocked activity. Blocking does not require a queue or storage node, as activities may be blocked as a result of delayed arrival of the input, when the activity is discrete,

When an activity is blocked or when the waiting line exceeds a certain number (or expected waiting time), then GERTS permits ordered balking. Here the program channels the arrival to another activity or other resource use. How, Phillips, Maggard, and Lesso (Refs.117 and 18) assumed that resources are homogeneous, or in other words a unit of resource used is applied equally effectively at any activity. This constraint used in GERTS QR can be relaxed without too much complication. Wolfe, Cochran, and Thompson (Ref. 14) expanded the GERTS QR node concepts by introducing a distinguisher node, which is realized when particular defined characteristics of the preceding activities are realized, and a storage node, which defines the primary and secondary storage resources used, as well as the resources of incident activities that can be blocked, and the node number to which incident activities can balk. A generator node is similarly defined which enables simulation of irregular arrivals, or the time between arrivals specified by a particular statistical distribution. As noted GERTS has become a very versatile project simulation method which permits effective and realistic evaluation of project performance with computational efficiency.

**A** very simple shipbuilding project example is next presented to show the application of GERTS. Figure 3 is a simplified flQw diagram of the flat stiffened panel construction part of a tanker shipbuilding project. The distribution of time and other resources required (labor, machine time) was established for each activity from existing data. Several of the activities (such as edge preparation, plate stripping, etc.) could be performed by more than one alternative machine (or activity) with its associated resource requirements. To assure optimum resource use in the simulation, activities were at the start ranked by efficiency of performance in terms of resource use. When queue lengths before such activity exceeded the amount which would affect the effective and more discrete progress of work on the panel line, the next arrival would balk and divert to the next best alternative activity (say gas stripper).. Activity costs were expressed in terms of both fixed and variable costs to permit consideration of idle time costs. The simulation provides:

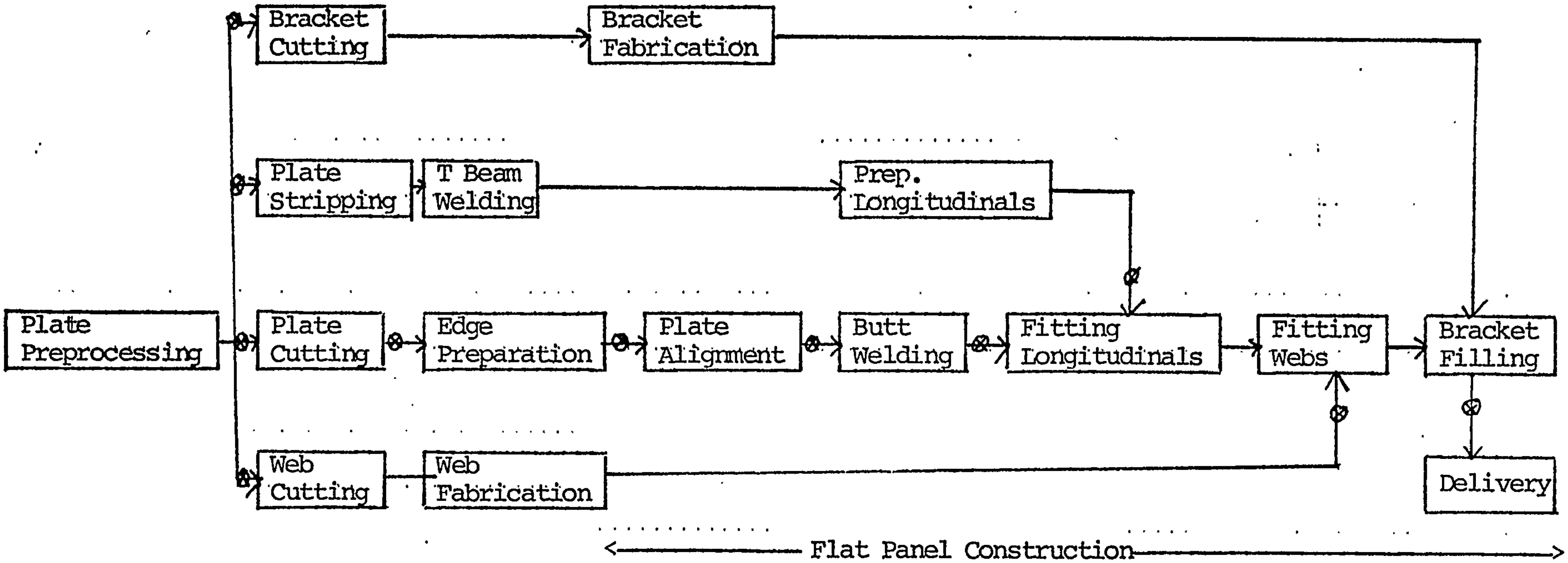



FIGURE 3 - FLOW DIAGRAM OF SIMPLIFIED FLAT STIFFENED PANEL CONSTRUCTION

1. Start and Finish Time of all jobs performed by the various activities.

2. Utilization of all activities and use of resources for **their** performance..

3. Time of waiting before each activity and variation of queue length at each buffer

4. Number of and time of occurrence of balking

5. Average distribution of time between the passage of a job between any two events (say between start of stripping and fitting of jongitudinals)

6. Throughput per unit time of the various activities and the total time.

The simulation was used to study various allocations of machine or activity capacities and the potential for reassignment of some machines to other projects. Methods of use of various machines or activities (and alternative manning) was similarly evaluated as was the effectiveness of existing or proposed buffer storage and interprocess handling. The approach was found to be an effective tool for the planning of shipbuilding projects. It is now proposed to study the use of this type of simulation for project management and control as well.

## Conclusions

After gaining experience with some limited applications of GERTS in the study of critical elements of the shipbuilding project such as flat stiffened panel construction, machinery (open sky) outfit (only major modules considered) and structural block or module assembly, it is now proposed to attempt the simulation of a complete shipbuilding project from the ordering of materials and equipment to the delivery and acceptance of a ship. While this will be done in the aggregate at the start, with most subnetworks of activities lumped into aggregate activities, it is hoped that it will show the way towards the development of a general approach to shipbuilding project planning under uncertainty and resource constraints.

## APPENDIX

## GERT (GRAPHICAL EVALUATION AND REVIEW TECHNIQUES)

(Extracted from RefJ. 11)

This network technique introduces conditional probability **of** activity use in addition to making the activity variable (time, cost, and other resources) random variables, which can be associated with most appropriate statistical distributions. In other words, in a GERT network, there are probabilities associated with each job or activity which represent the relative frequency of the occurrence of the activity within the network or the probability that the job will be performed. When an activity is used or a job is performed, it is said to be realized. This concept of Deslization obviously applies similarly to events connecting the activities.

In the simplest case we assume that each activity of the project network has two parameters associated with it:

1. $t_i$ - time or cost required for the performance of activity, i, a random variable with associated statistical measures
2. $p_i$ - the probability that activity i is performed, given that the starting event for the activity is realized
3. $P_j$ - the probability that event j is realized
4. $T_j$ - time of realization of event j. ($T_j$. = expected time of realization of event j)

**To** apply GERT we go through the following steps:

1. Convert qualitative information of jobs, their relations, and alternative jobs.
2. Collect the data on activities comprising the network
3. Develop statistical distributions or averages for the resources required for the performance of each job. (In our case, only time.)
4. Obtain equivalent single line function between any two events (nodes) of the network.
5. Convert equivalent single line function into performance measures comprised of the probability that a specific event is realized and the moment generating function of the time or cost associated with the equivalent network.
6. Make inferences concerning the system response.

GERT defines events or nodes by different types of input and output characteristics:

a. Exclusive-or Input - only one of the branches leading into the node can be realized.

b. Inclusive-or Input - any branch leading into the node realizes it, but time or cost of realization is always the smallest of the completion times of the activities leading into the node.

C. And Input - only realized if all activities (branched) leading into the node are realized. Time or cost of realization is always largest of incoming activity times. This is therefore equivalent to a PERT node.

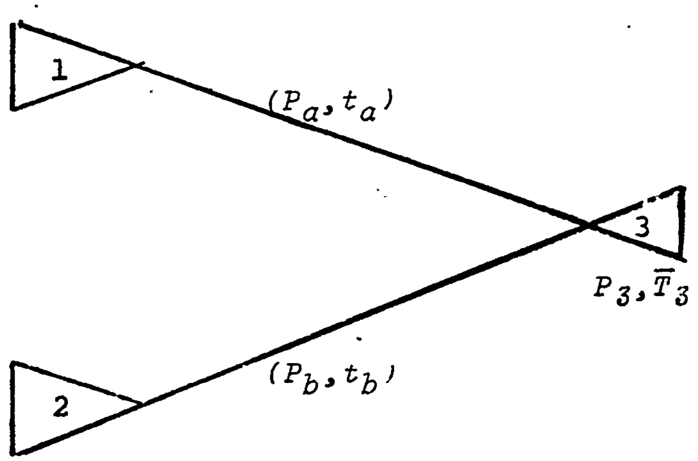
d. Deterministic Output - all activities leading from the node must be performed if probability of realization equal to one.

e. Probabilistic Output - exactly one and only one activity emanating from the node can be performed if the node is realized.

Each node of event is represented by one of the input and one of the output characteristics.

In Exclusive-or Node Networks or subsets of networks feedback is possible. If all the inputs or events of a network are Exclusive-or, then either all node outputs are probabilistic, or the activities following a deterministic output are independent (nontouching, disjoint).

In some networks And and Inclusive-or Nodes can be converted to Exclusive-or Nodes. Considering an Exclusive-or Mode with two_ inputs where P. is the probability that node i is realized, and $T_i$ is the expected time that node i is realized,.given it is realized,



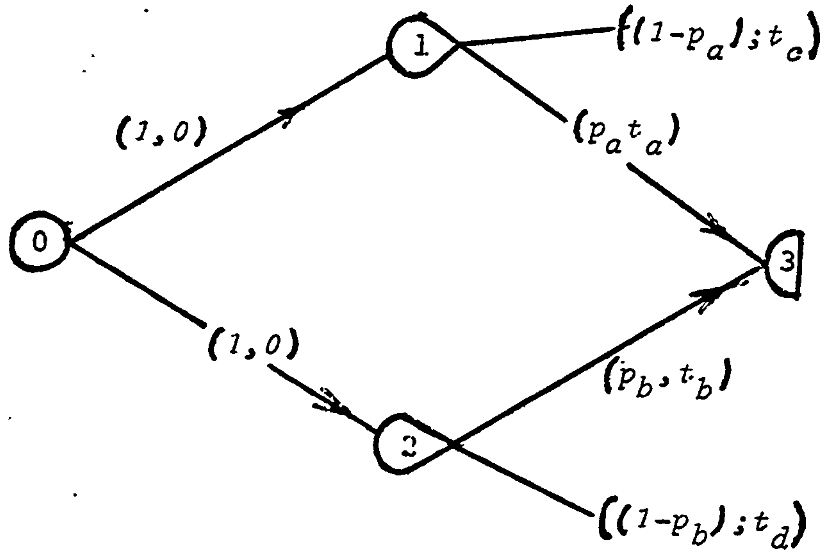

$$P_3 = P_1 \, p_a + P_2 \, p_b$$

$$\bar{T}_3 = \frac{P_1 \, p_a \, (\bar{T}_1 + t_a) + P_2 \, p_b \, (\bar{T}_2 + t_b)}{P_1 \, p_a + P_2 \, p_b}$$

If $P_1 = P_2$, then $\bar{T}_1 = \bar{T}_2$ and $P_3 = P_1(p_a+p_b)$ and $\bar{T}_3 = T_1$

$$+ \frac{p_a t_a + p_b t_b}{p_a + p_b}$$

Considering next an And Node Network,



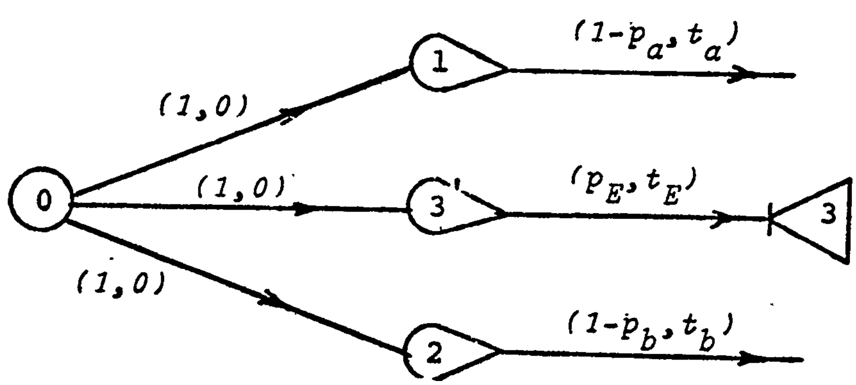

As node 3 is only realized if a and blare realized and the probability of a and b being realized is $P_1 P_a$ and $P_2 P_b$ respectively, the probability that both are realized is the intersected or joint event of both being realized.

$$P_3 = P_{1 \cap 2}\, p_a\, p_b$$

$$\bar{T}_3 = max \quad (T_1 + t_a, \; ; \; T_2 + t_b)$$

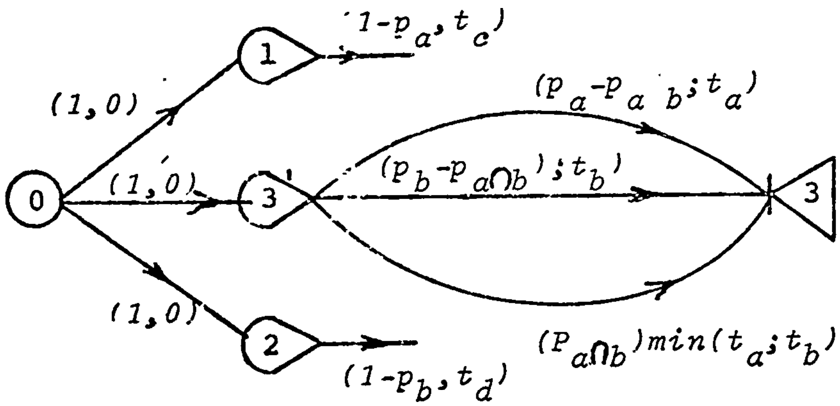
It should be noted that the expected value of the maximum is not always the maximum of the expected value.

An Exclusive-or relation can replace the And node at node 3 as shown.



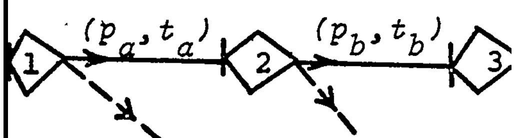
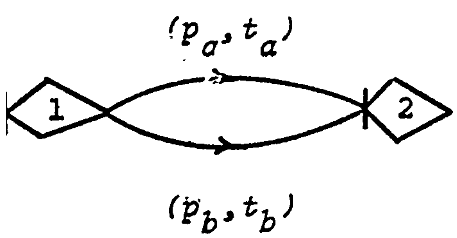
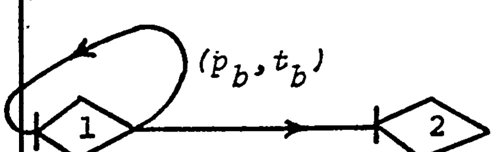
**where** $P_E = p_a p_b$ **and** $t_E = max\ (t_a, t_b)$

For an Inclusive-or relation the analysis is as in the And case and we get for the previous network now,




The reduction basically involves enumeration of all mutually exclusive alternative methods of realizing node *3* from node 0.

<u>Simple Exclusive-Or Networks</u>

| Network Type | Representation With Constant Times | Equivalent Probability | Equivalent Expected Time |
|---|---|---|---|
| **a) Serles** |  | $P_a P_b$ | $t_a + t_b$ |
| **lb) Parallel** |  | $P_a + P_b$ | $\frac{P_a t_a + P_b t_b}{P_a + P_b}$ |
| **c) Self Loop** |  $(P_a t_a)$ | $\frac{P_a}{1 - p_b}$ | $t_a + \left(\frac{p_b}{1-p_b}\right) t_b$ |

The relation between GERT networks, PERT, flowgraphs, and stochastic networks can be stated as:

PERT networks are equal to GERT networks with all And deterministic nodes, in which case all activities must be performed.

FLOWGRAPHS are stochastic networks with a single multiplicative parameter (all additive parameters such as time are set zero) and the probabilistic interpretation for the multiplicative parameter is removed.

To facilitate operation with a general conditional stochastic network (GERT) which permits simultaneous handling of multiplicative and additional parameters (such as probabilities and times or costs in a series network) we use a transformation of p and t into a single function such as $w(s) = pe^{st}$ when, for instance, for two activities in series w(s) function will be multiplied and for 2 activities in parallel with w(s) functions would be added. If we then differentiate with respect to s and set s=O we will get an expression proportional to the expected times. The function w(s) is normally called the moment generating function, MGF.

If $w_E(8)$ is the equivalent MGF for a complete network, **then**

$$p_E = \text{equivalent probability} = w_E(0)$$

For instance, for two activities in series,

$$W_E(8) = w_1(8)\,w_2(8) = \left(p_1 e^{st_1}\right)\left(p_2 e^{st_2}\right)$$

**and** $p_E = w_E(0) = p_1 p_2$ **as** desired.

For two parallel activities,

$$w_E(8) = W_1(8) + W_2(8) = p_1 e^{st_1} + p_2 e^{st_2}$$

$$P_E(0) = P_1 + P_2$$

To find the expected equivalent **time** for **two activities in series,**

$$p_E \cdot E(t) = \left.\frac{\partial w_E(s)}{\partial s}\right| = P_1 P_2 (t_1 + t_2)$$

and for two activities in parallel,

$$P_E \cdot E(t) = \left.\frac{\partial w_E(s)}{\partial s}\right|_{s=0} = P_1 t_1 + P_2 t_2$$

Therefore, by dividing the derivative set to s=O by the equivalent probability we obtain the equivalent expected time E(t).

To employ the w(s) function effectively we use flow graph theory. The $w_E(s)$ or equivalent MGF of a complex network is obtained by Mason's rule or a similar flow graph reduction approach.

## Fundamental GERTS Concepts

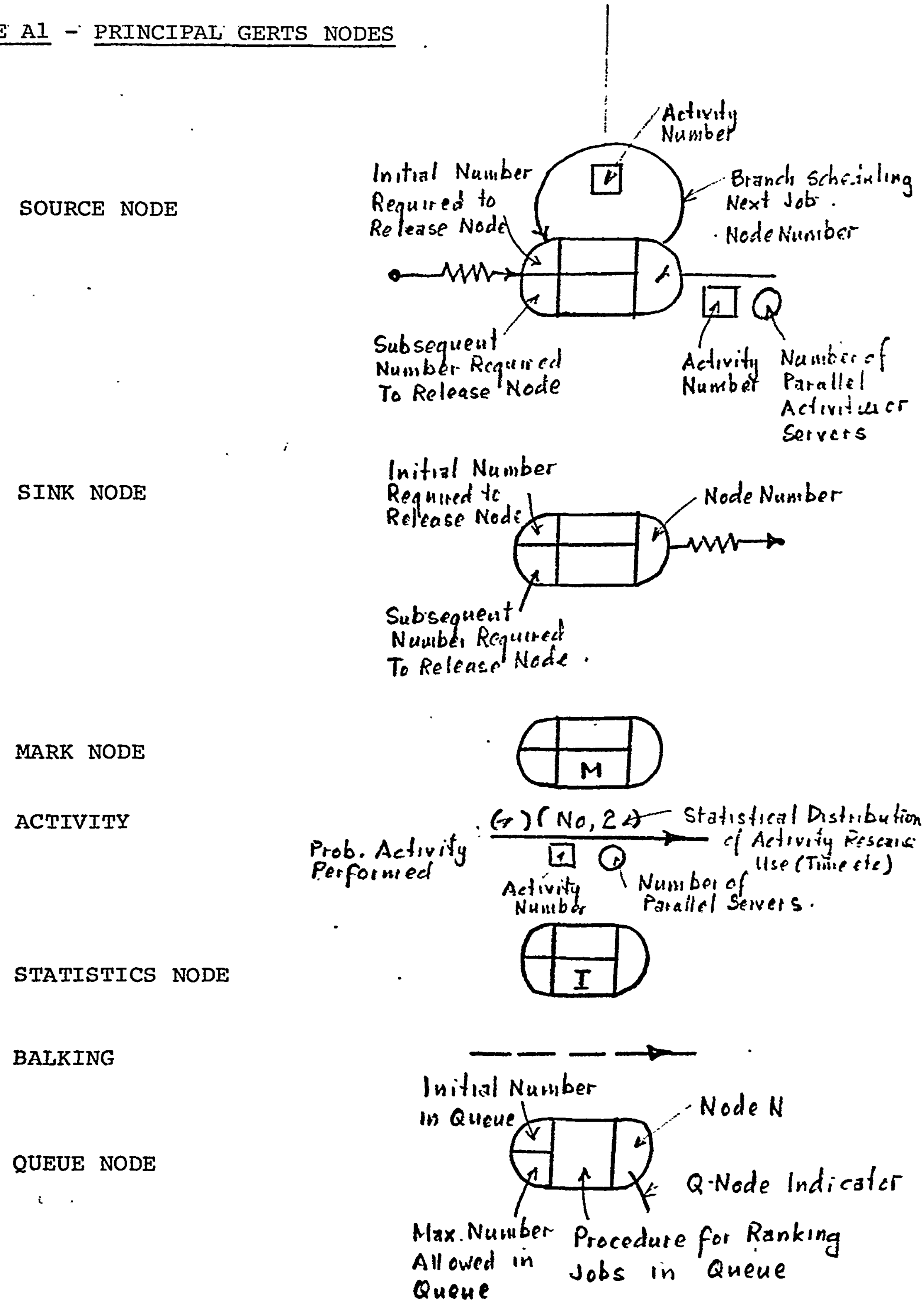
GERTS or GERT Simulation and their derivatives use a number of imaginative node definitions which provide a large amount of flexibility in analyzing and evaluating shipbuilding project performance, resource use, schedules, and more. GERTS nodes can have probabilities or stochastic output and input. The basic node characteristics are shown in Figure Al. It should be noted that nodes can have a deterministic (semi-circular) or probabilistic (triangular) input or output, in which case not all incoming activities are required to realize the node nor do all outgoing activities have to be performed.

In addition to the nodes shown there are regular or standard nodes, which only perform the function of receiving and routing jobs. Statistical Distributions are designated by codes such as:

| | |
|---|---|
| BE | Beta Distribution |
| BP | Beta Distribution fitted to three parameters |
| co | Constant Distribution |
| ER | Erlang Distribution |
| EX | Exponential Distribution |
| GA | Gamma Distribution |
| LO | Log normal Distribution |
| NO | Normal Distribution |
| PO | Poisson Distribution |
| TR | Triangular Distribution |
| UN | Uniform Distribution |

It is noted that GERTS permits use of most practical distributions in simulating a project.

FIGURE A1 - PRINCIPAL GERTS NODES



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18. G. L. Hogg, D. T. Phillips, M. J. Maggard, W. G. Lesso, "GERT QR: A Model for Multi-Resource Constrained Queueing Systems - Part II: An Analysis of Parallel Channel, Dual Resource Constrained Queueing System with Homogeneous Resources", Transactions, AIIE, June 1975.

# COMPUTERVISION INTERFACE TO BATCH ELECTRIC BOAT PIPING PROGRAMS

Laurence J. McKee
Senior Software Engineer
General Dynamics/Electric Boat Division
Groton, Connecticut

Mr. McKee is currently responsible for development of interfaces to and from the Electric Boat Division piping design analysis and assembly programs to computervision. He has developed an interface between computervision and AUTOKON.

Mr. McKee holds a BS degree from Hofstra University Hempstead, New York.

Robert Sciullo
Manager Material
General Dynamics/Electric Boat Division
Groton, Connecticut

Mr. Sciullo's functions include computer system development and control and computer generation of pipe details which provided a logical conversion from batch to graphic terminals. Additional responsibilities are in the areas of material identification and sourcing; drawing control and issues; and contract definition and budgets. Data systems interface provides for involvement in virtually all aspects of engineering products and the interfaces with shipyard construction activities.

Mr. Sciullo attended Thames Valley State Technical College and Carnegie Institute of Technology.

## ABSTRACT

The design and implementation of the computervision interface to the batch electric boat piping design analysis and assembly programs will be described. This interface will allow three-dimensional piping models produced on computervision to be processed by the Electric Boat Piping programs on the UNIVAC. The end result of this processing,would be assembly details which are delivered to the pipe shop for assembly.

# Background

COMPUTERIZED PROGRAMS FOR PIPING SYSTEM EVOLUTION

1. Provided pipe bending data for length, bend angles, roll angles, and distance between bends.
2. Added fitting, valve, and hanger locations to both bent and straight pipe by match marking and creating pipe details.
3. Combined details into assemblies.
4. Generated isometric and orthographic drawings.
5. Added welding identification and data.
6. Extracted and added material information.
7. Expanded to include work authorizations, trade work instructions, feed relationships, test boundaries, and serialization.
8. Generated tapes for data transfer to work authorization files and reports for manufacturing and installation.

■ JUL 31, 1978  508-4644096  DET FWC TRIM SAN TK 1 & 2

GENERAL DYNAMICS / ELECTRIC BOAT DIVISION

DATE ____________ BOAT NO. ____ S.O. ______________

PIPEFITTER & BADGE NO. ______________________

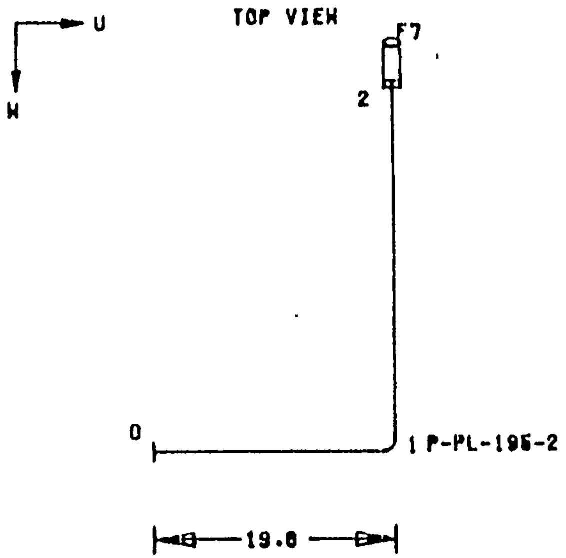
SUPERVISOR ______________________

| PLAN | PIPE | DET | REV | APPLICABILITY |
|---|---|---|---|---|
| 87523-1307 | P-PL-195-2 | QQ | A | |
| | | WBR | | 2.5 FLOOR 38 |

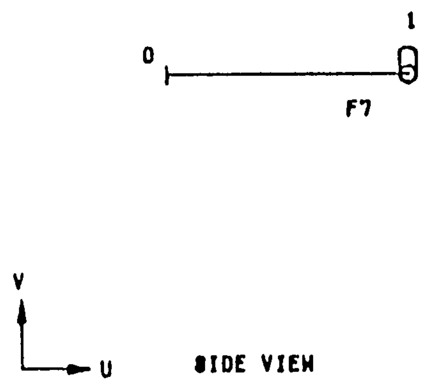
| PT NO | DELTAS U | V | W |
|---|---|---|---|
| 0-1 | 19.8 | .0 | .0 |
| 1-2 | .0 | .0 | -30.1 |

| BEND | ROLL ANGLE | BEND ANGLE | DIST WIRE | PBR | | DIST PIPE | STRAIGHT PIPE | CLAMPING OR FITUP | END JOINT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 90 | 17.3 | 50 | 7.5 | 12.3 | 12.3 | .0 | SB |
| | 90 | | 48.8 | | | 46.7 | 22.6 | .0 | SB |

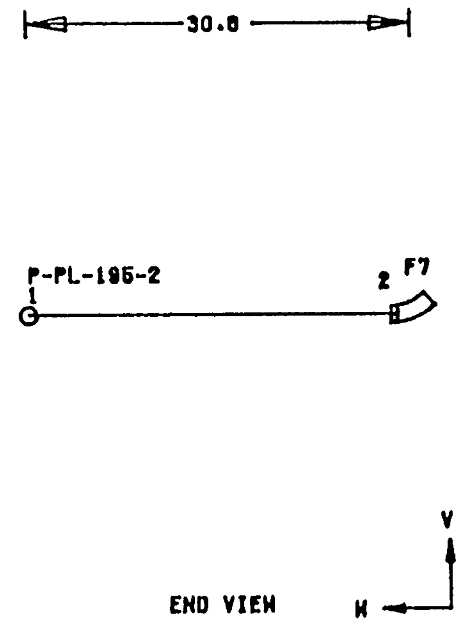
LENGTH END TO END = 36.0 INCHES




TOP VIEW




SIDE VIEW



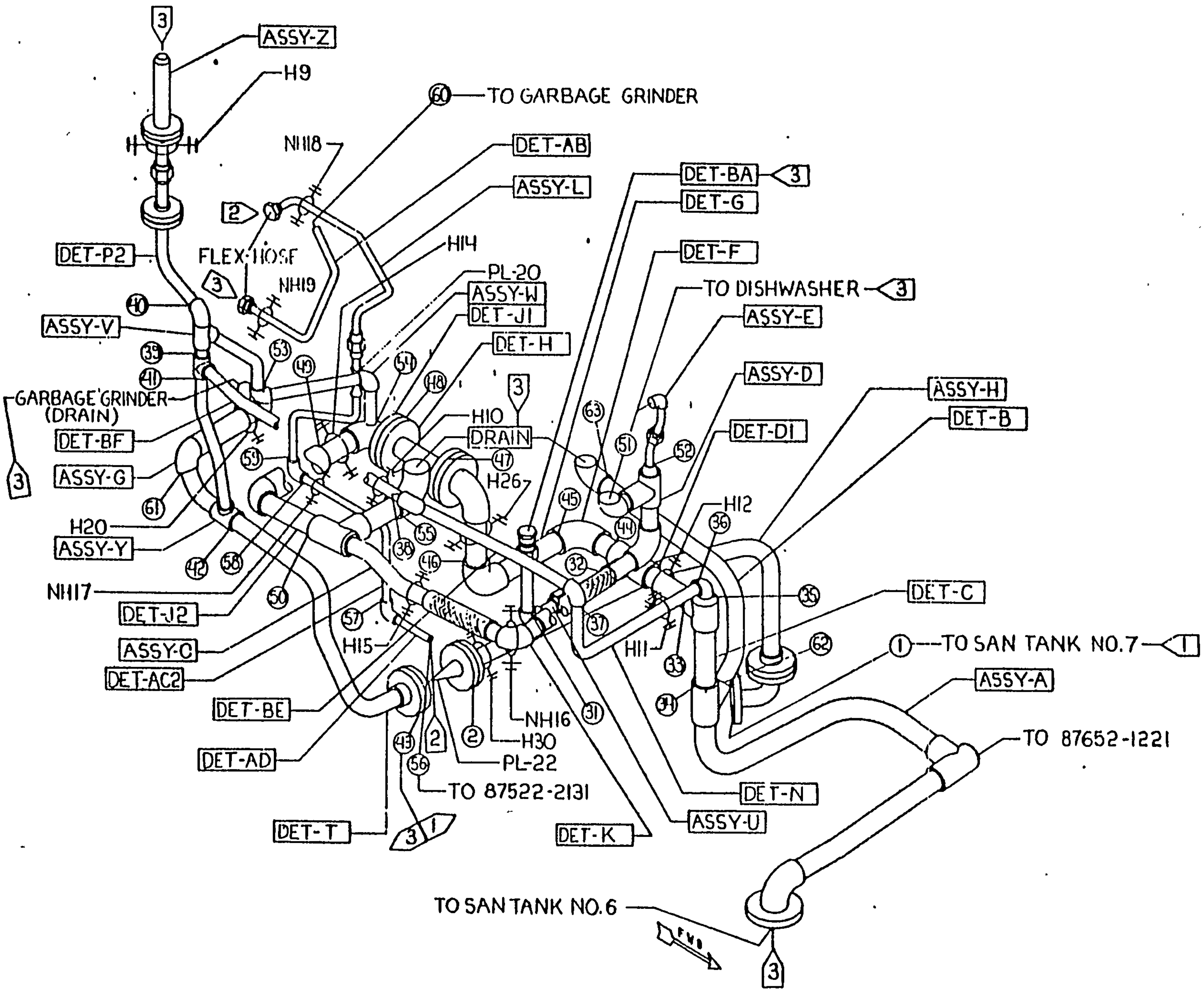

END VIEW

LIST OF MATERIALS

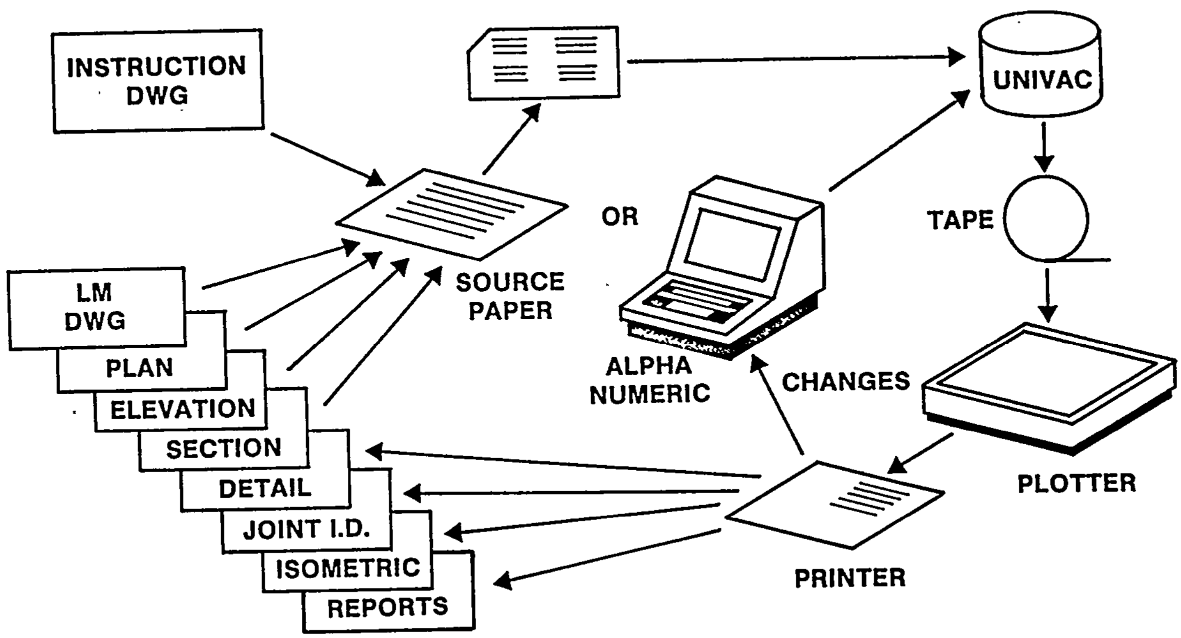
| ITEM NO / NO SEQ | QTY / CLASS | UM MF QTY / LV MF UM | NOUN NAME / SIZE | TYPE | MODIFIER / MATERIAL | DOCUMENT OR / DRAWING | PART NO / SOURCE | ROUTING / REMARKS |
|---|---|---|---|---|---|---|---|---|
| P-PL-195 | 47 | IN | TUBE | | | MIL-T-16420 | 46-65-0061 | |
| 0005 | P-3B | NA | 1.90000 X 0.134MIN | | CUNI | TY 1 OR 2 70-30 | | |
| F7 | 1 | PC | ELBOW | 45 | SB | MIL-F-1183 | 15-00-4513 | |
| 2007 | | NA | 1.500IPS 400PSI | | BRZ | TY A | | |
| F1 | 1 | PC | SLEEVE | PEN | | 2621-601-09 | 262160109-0063 | |
| 2001 | | NA | 1.500IPS 4.500LG | | STL | PC 63 | WAA-A7020005000 | |

FABRICATION
ATTACH F7 AT POINT 2 AT JOINT IDENT. NO. 048-01-033
F7 (AT POINT 2) ATTACHED TO P-PL-195-1 OF DETAIL Z AT JOINT IDENT. NO. 048-01-032
ATTACH F1 TO P-PL-195-2

NOTE: INCLUDES
CONTROLLED AND
NON-CONTROLLED JOINTS

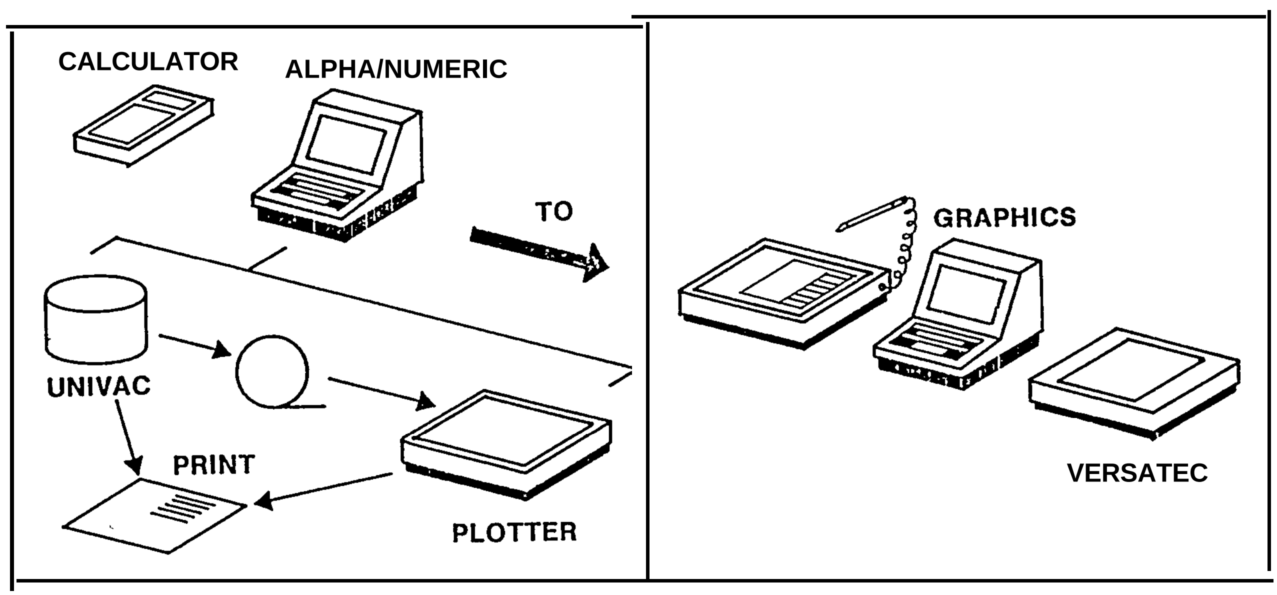

ASSY-Z
H9
TO GARBAGE GRINDER
NH18
DET-AB
ASSY-L
DET-BA
DET-G
DET-F
TO DISHWASHER
ASSY-E
ASSY-D
ASSY-H
DET-B
DET-D1
FLEX HOSE
NH19
H14
PL-20
ASSY-W
DET-J1
DET-H
DET-P2
ASSY-V
GARBAGE GRINDER (DRAIN)
DET-BF
ASSY-G
H10
DRAIN
H26
H12
H20
ASSY-Y
NH17
DET-J2
ASSY-C
DET-AC2
H15
DET-BE
DET-AD
NH16
H30
PL-22
TO 87522-2131
DET-T
DET-K
DET-N
ASSY-U
DET-C
H11
TO SAN TANK NO.7
ASSY-A
TO 87652-1221
TO SAN TANK NO.6
FWD

# Background (Cont'd)

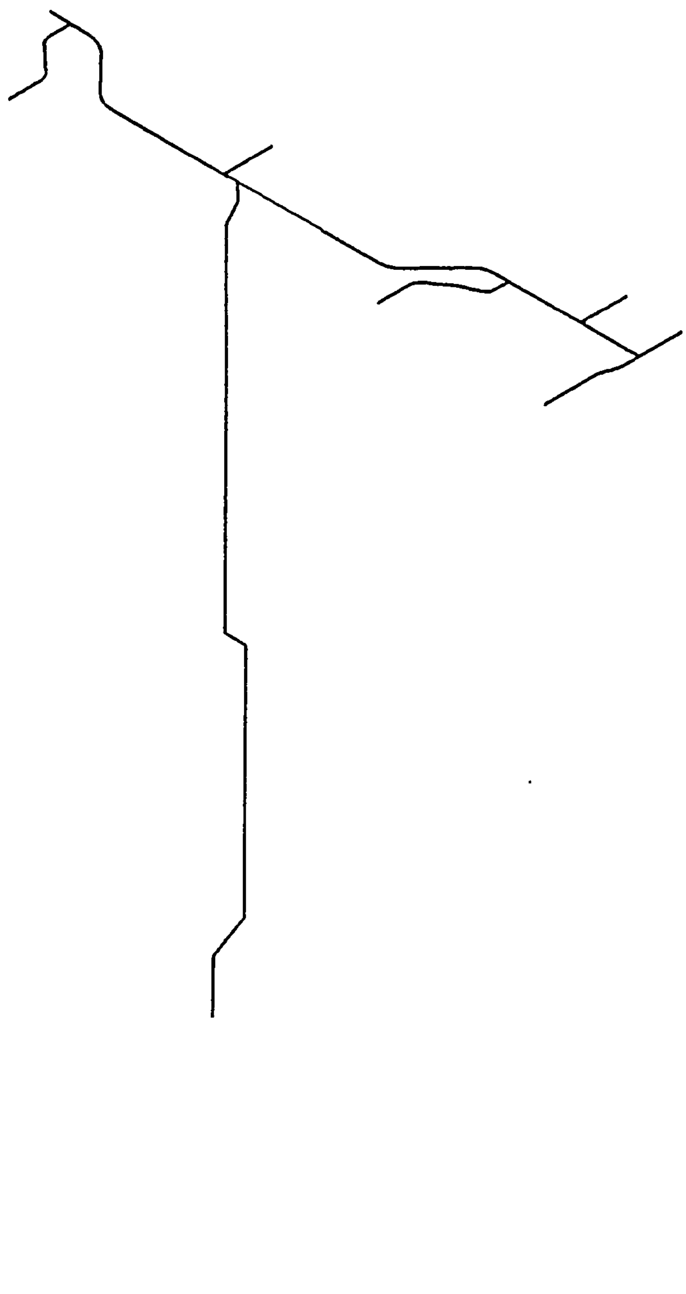



# Transition

**STATE OF THE ART ALLOWS A CHANGE IN SKILL LEVEL AND REDUCTION IN WALL TIME.**



# Isometric of Modeled Pipeline Routed with Bends



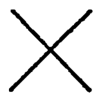
# Approach

- MUST BE TECHNICALLY EQUAL TO EXISTING PRODUCTS.
- MUST BE COST-EFFECTIVE WITH REAL BENEFITS (MANHOURS AND WALL TIME).

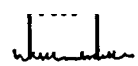
- ESTABLISH PLAN AND MILESTONES

1. Training on CADDS 3

2. Execution on CADDS 3



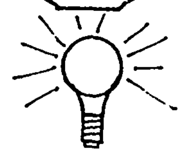
3. Mods/workarounds CADDS 3



CADDS 3

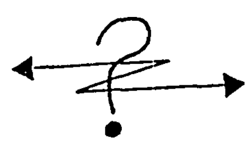
4. Training on CADDS 4

5. Execution on CADDS 4



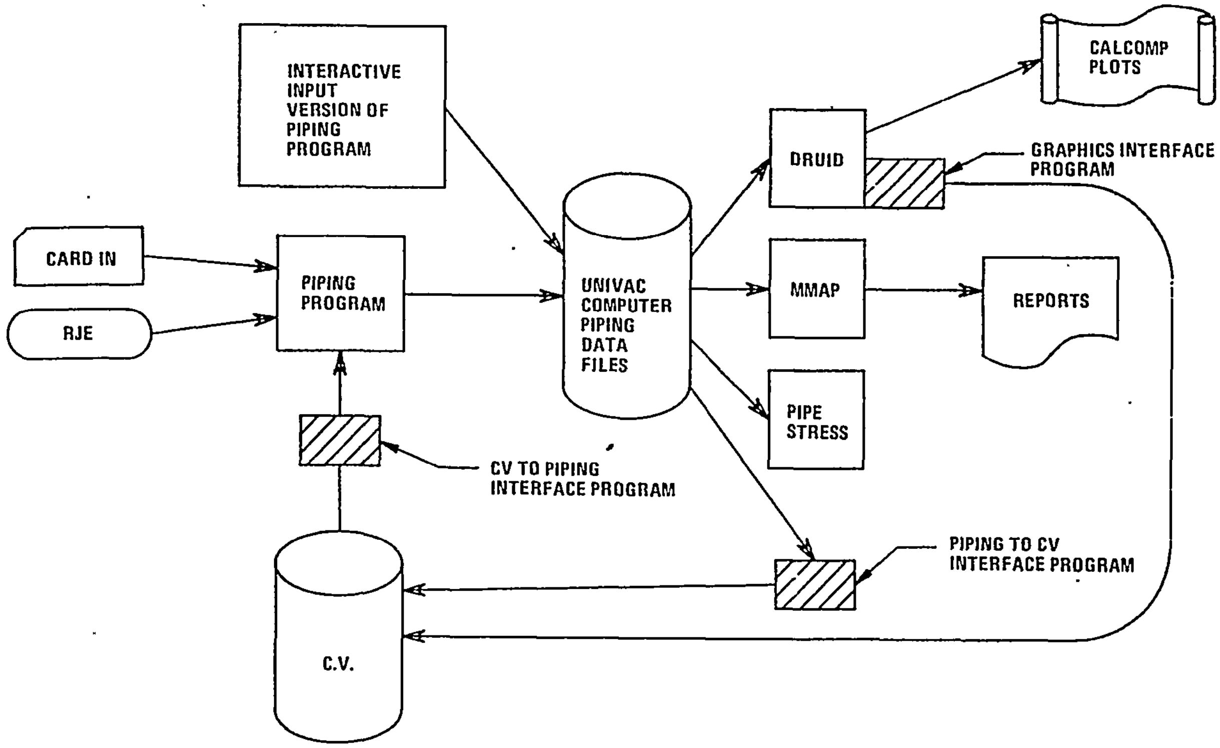
6. Mods/workarounds CADDS 4

7. CADDS 4 ⟶ IN / UNIVAC ⟶ OUT



8. Committee programming/data flow

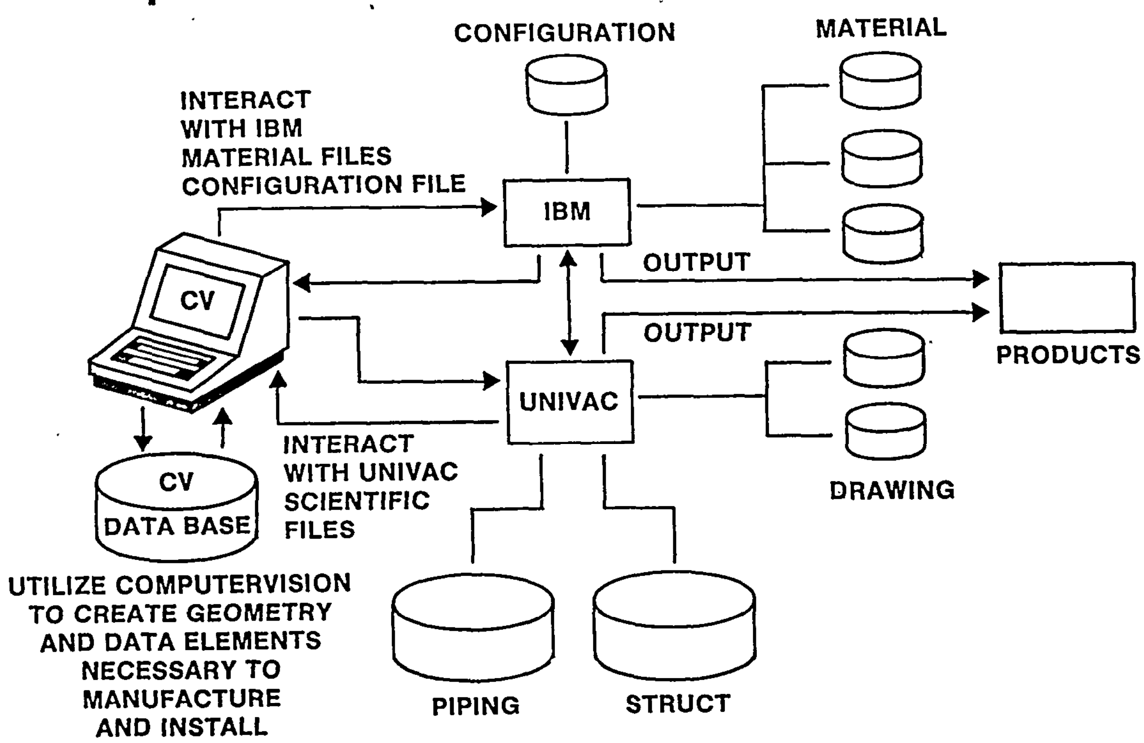
# Computervision/Univac System Flow Chart




# Approach (Cont'd)

- PROGRAMMING - IN-HOUSE OR CV? ~~CV~~
- DATA FLOW
  1. CV → IBM → UNIVAC — INTELLIGENCE
  2. UNIVAC → CV — DUMB
  3. UNIVAC → IBM → CV — INTELLIGENCE
- TEST AND ACCEPTANCE
  1. Equal products
  2. Time trial - Machine — ~~6~~ vs 5
  3. Time trial - Human

## Proposed Detail Data Flow For CAD/CAM




# Creating A Pipe Detail With Bend and Match Mark Data

COMPARISON OF BATCH TO COMPUTERVISION

## Step 1

BATCH (8 hrs, 1 day)

Obtain Cartesian coordinates from mockup, layout, shipcheck, etc.

COMPUTERVISION (8 hrs, 1 day)

Obtain Cartesian coordinates from mockup, layout, shipcheck, etc.

## Step 2

BATCH (20 hrs, 2-1/2 days)

Fill out source paper for key punch.

COMPUTERVISION (12 hrs, l-1/2 days)

Model piping system.

## Step 3

BATCH (3 hrs, l-1/2 days)

Run PIPER program until error-free. Run DRUID program for isometric or orthographic plots.

COMPUTERVISION (2 hrs, 1 day)

CV data base interfaced to DRUID for isometric or orthographic plots.

## Step 4

BATCH (2 hrs, 1 day)

MMAP Interface program - pipe details

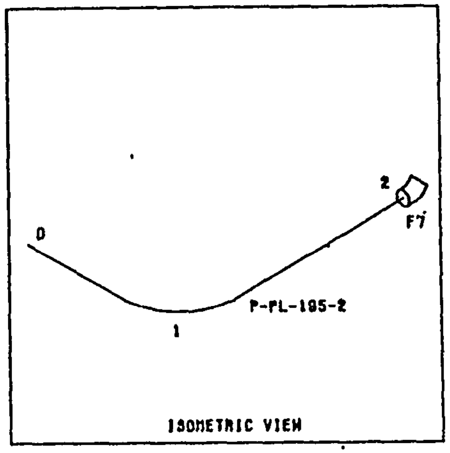
COMPUTERVISION (2 hrs, 1 day)

MMAP Interface program - pipe details

## Totals

BATCH - 36 hrs, 7 days

COMPUTERVISION - 24 hrs, 4-l/2 days




ISOMETRIC VIEW

* AUG 25, 1982 508-4644095 DET FHG TRIM SAN TK 1 & 2
DATE ________ BOAT NO. ___ S.O. ________
PIPEFITTER & BADGE NO. ________
SUPERVISOR ________

GENERAL DYNAMICS / ELECTRIC BOAT DIVISION

| PLAN | PIPE | DET | REV | APPLICABILITY | SHEET |
|---|---|---|---|---|---|
| 87523-1307 | P-PL-195-2 | AA | K | ABCDEF | 27 |

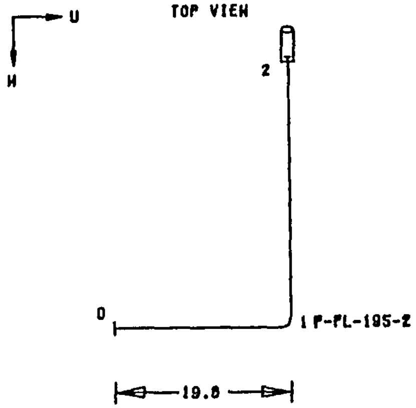
·WBR 2.5 FLOOR 36

| PT NO | DELTAS U | V | W |
|---|---|---|---|
| 0-1 | 19.8 | .0 | .0 |
| 1-2 | .0 | .0 | -30.1 |

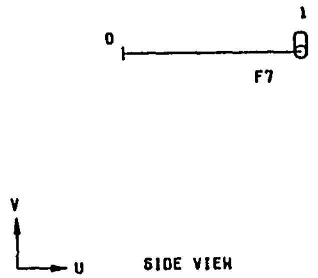
LENGTH END TO END = 36.0 INCHES

| BEND | ROLL ANGLE | BEND ANGLE | DIST WIRE | PDR | | DIST PIPE | STRAIGHT PIPE | CLAMPING OR FITUP | END JOINT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 90 | 17.3 | 50 | 7.5 | 12.3 | 12.3 | .0 | 58 |
| | 90 | | 48.8 | | | 46.7 | 22.8 | .0 | 58 |

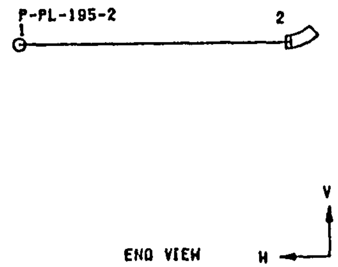
30.8




TOP VIEW




SIDE VIEW



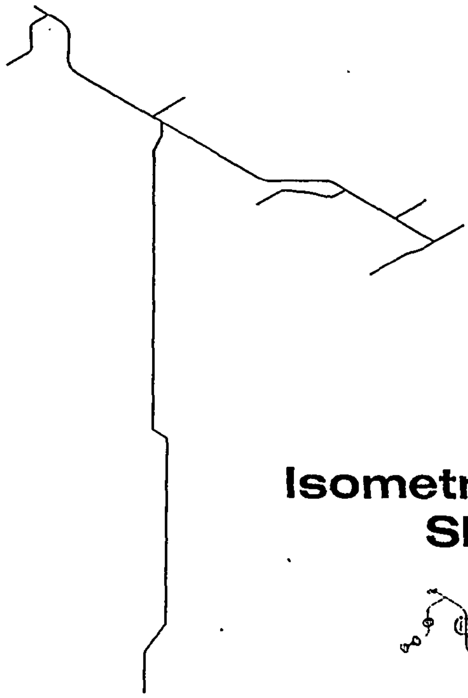

END VIEW

LIST OF MATERIALS

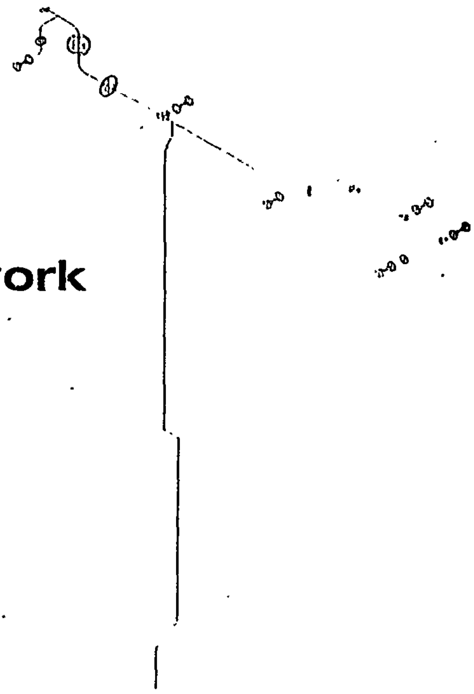
| ITEM NO NO | SEQ | QTY CLASS | UM LV | NOUN NAME SIZE | TYPE | MODIFIER MATERIAL | DOCUMENT OR DRAWING | | PART NO TON-N REQ |
|---|---|---|---|---|---|---|---|---|---|
| P-PL-195 | | 47 | IN | TUBE | | | MIL-T-16420 | CL 1650 | 48-65-0061 |
| | 0005 | P-3B | NA | 1.900OD X 0.134MIN | | CUNI | TY 1 OR 2 70-30 | | |
| F7 | | 1 | PC | ELBOW | 45 | SB | MIL-F-1183 | | 15-00-4513 |
| | 2007 | | NA | 1.500IPS 400PSI | | BRZ | FIG 7 TY A | | |
| F1 | | 1 | PC | SLEEVE | PEN | | 2821-801-09 | ASTM-A441 | 262160109-0053 |
| | 2001 | | NA | 1.500IPS 4.500LG | | STL | PC 53 | | |

FABRICATION
ATTACH F7 AT POINT 2 AT JOINT IDENT. NO. 048-01-033
F7 (AT POINT 2) ATTACHED TO P-PL-195-1 OF DETAIL Z AT JOINT IDENT. NO. 048-01-032
ATTACH F1 TO P-PL-195-2
PAINT WITH EPOXY COATING SYSTEM

## Isometric of Modeled Pipeline Routed with Bends

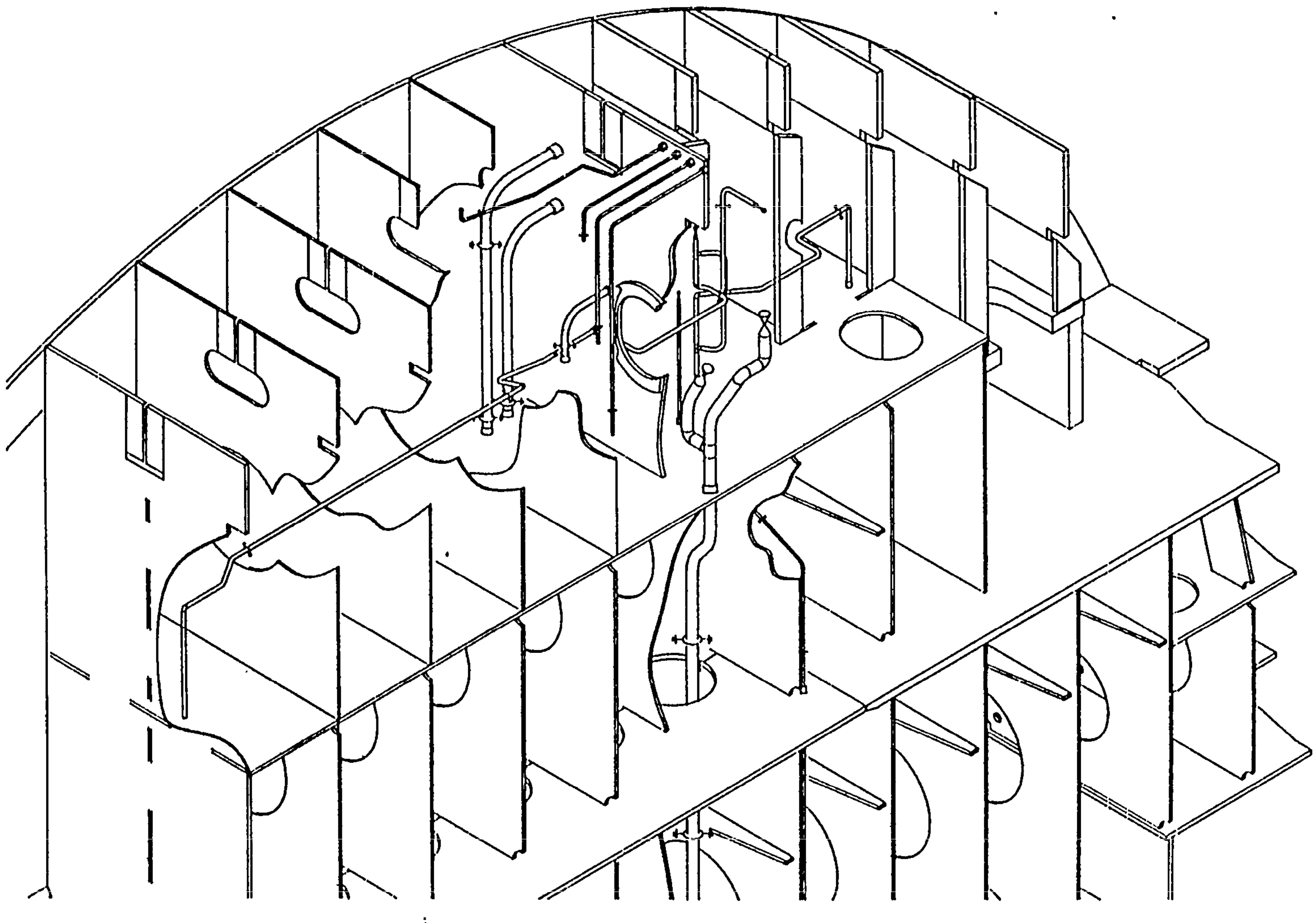


## Isometric of Piping Network Showing Fittings

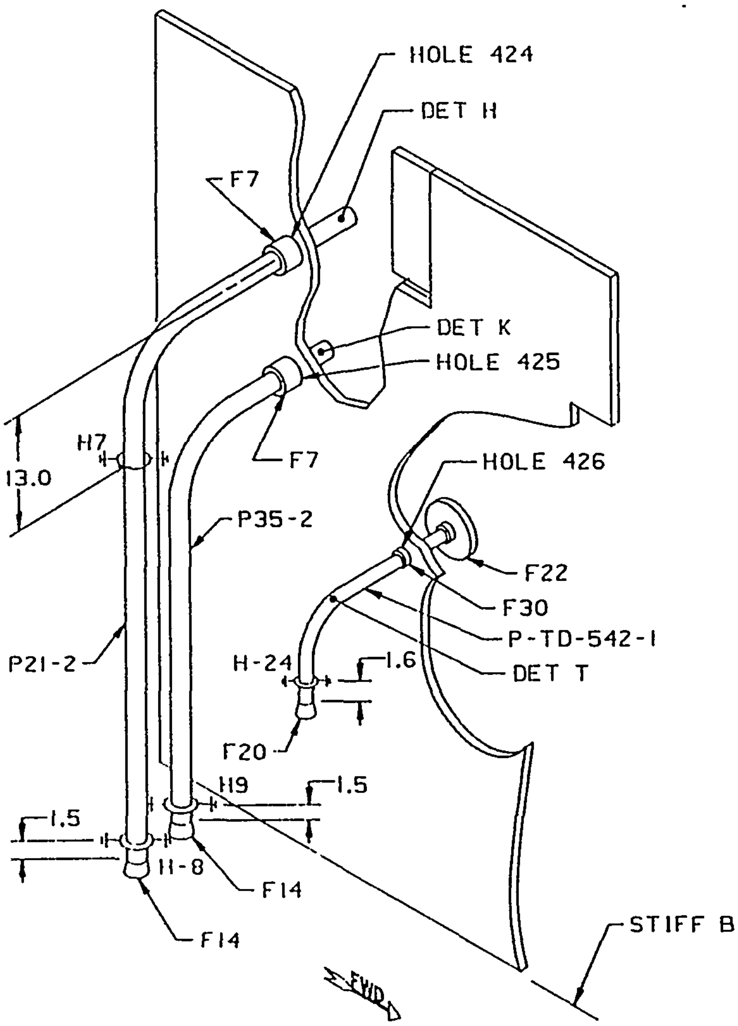


## Plan View of Piping Network

# Cutaway Isometric Showing Combination of Piping and Structural Systems



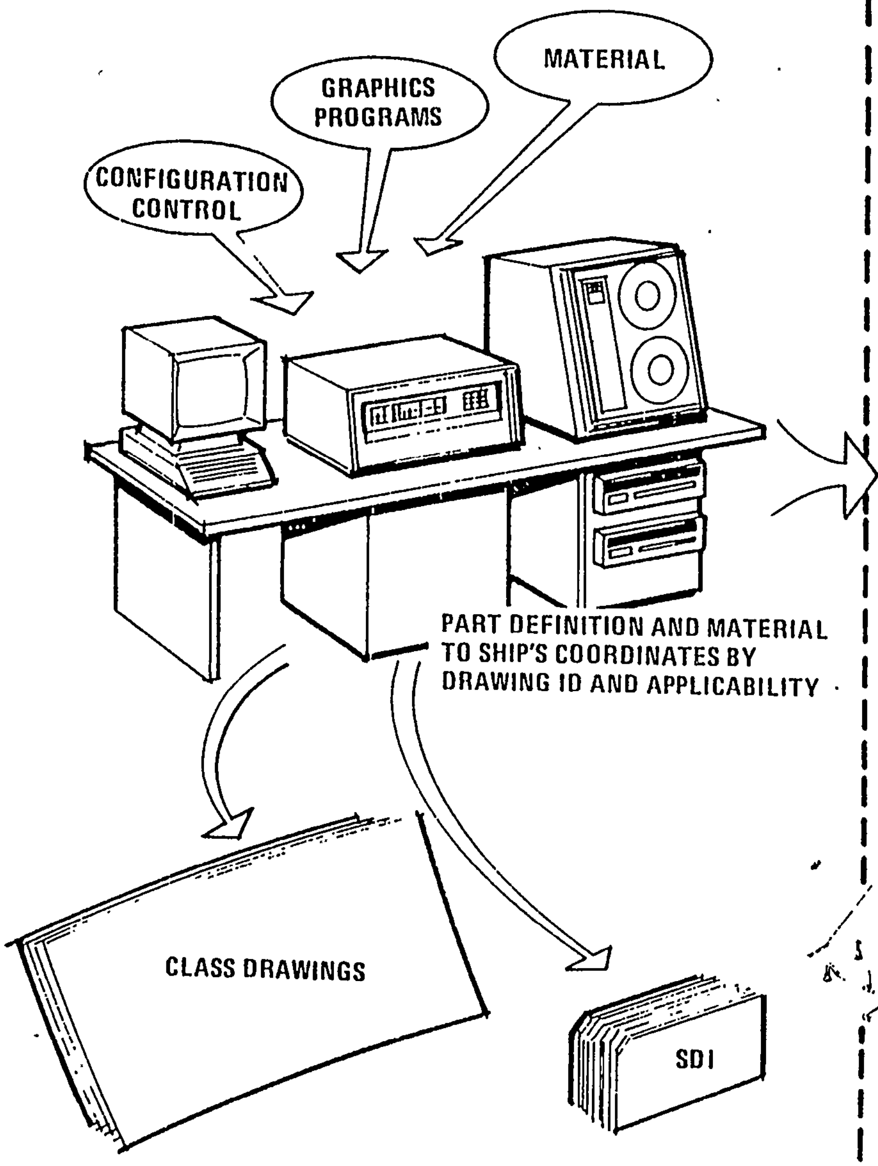
# Labeled Isometric Showiing Pipe Penetrating Structure



# Results

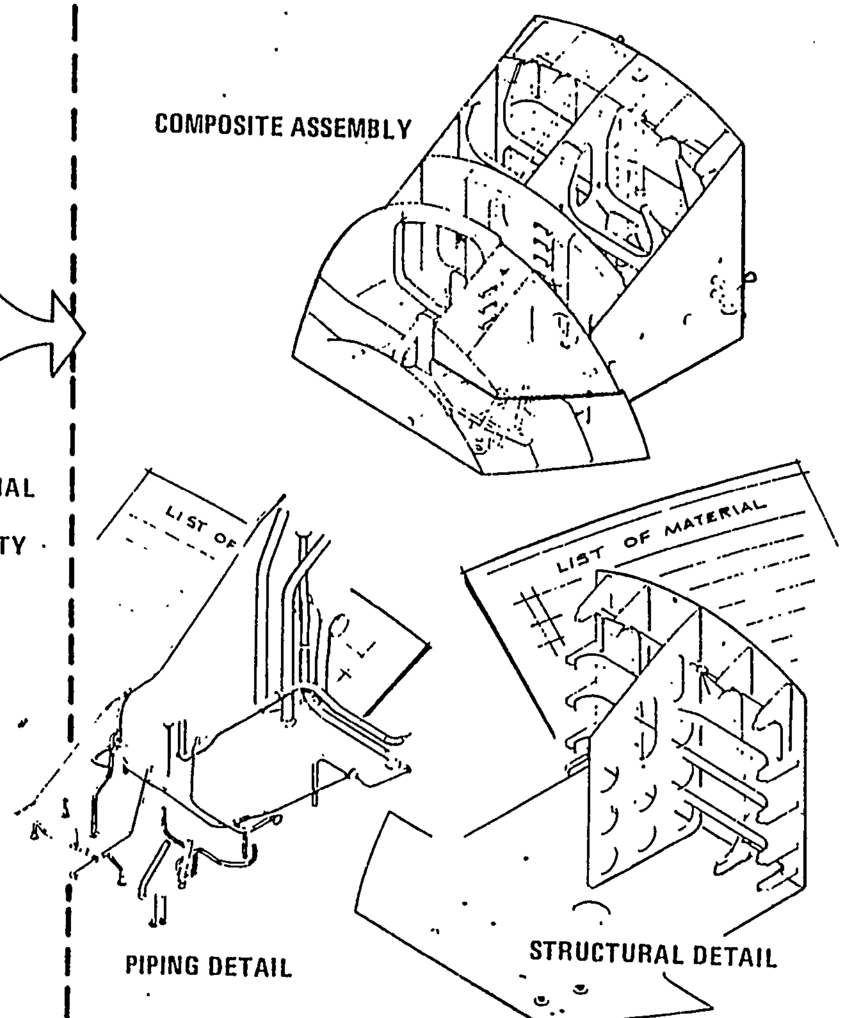
- PROMISING
- **CAN GENERATE PRODUCTS**
- MARRY EXISTING TECHNOLOGY WITH NEW **TECHNOLOGY**
- MODS/WORKAROUNDS ARE ESSENTIAL
- USERS AND PROGRAMMERS MUST WORK AS A TEAM
- SIDE BENEFITS

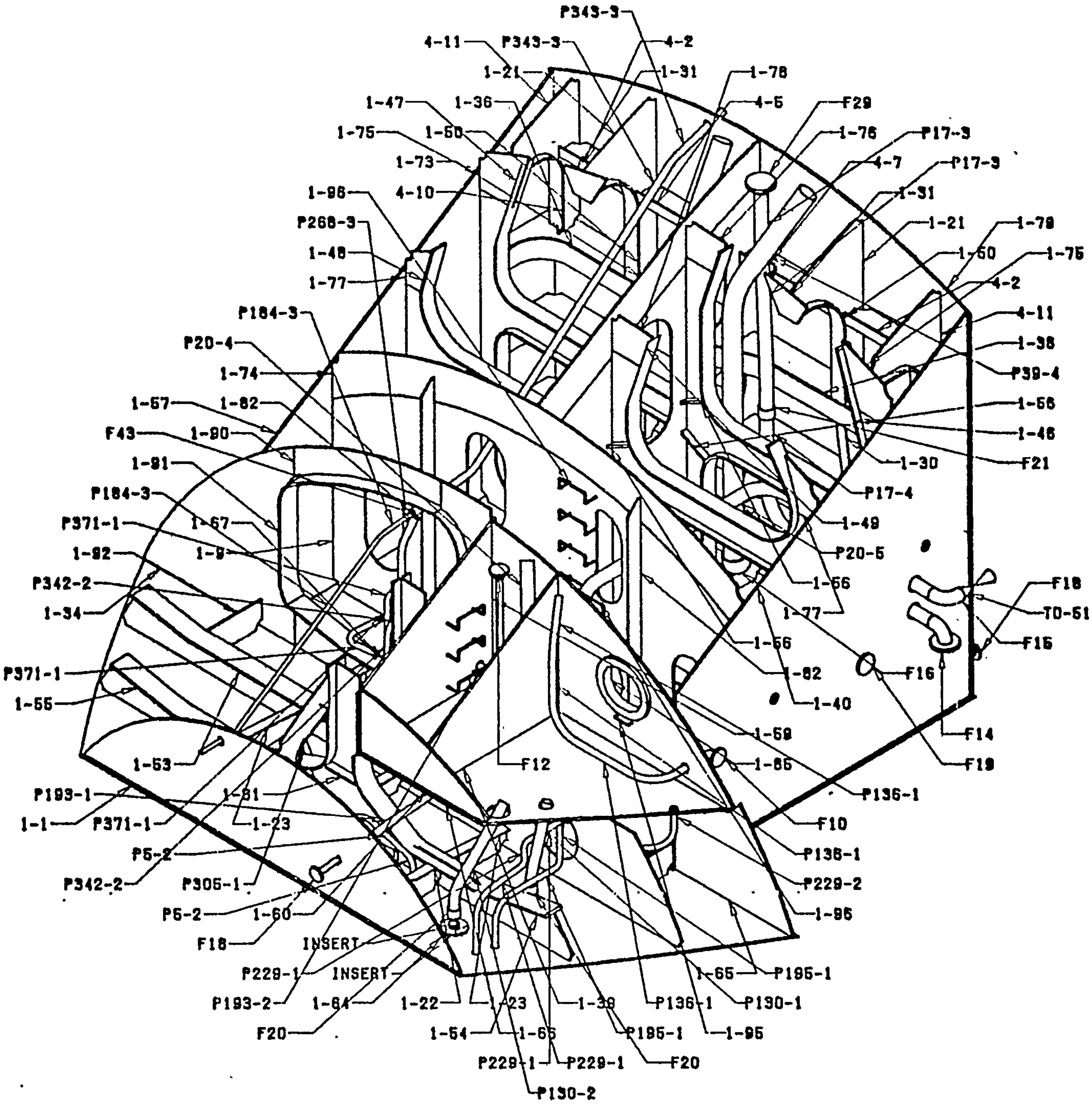
# Capture & Control Data




# Package Work

IN ACCORDANCE WITH SHIPYARD WORK AUTHORIZATIONS AND SCHEDULES






ISOMETRIC
1/32 SCALE 3/8 IN/FT

# NAVY COMPUTER-AIDED SHIP DESIGN

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Naval Sea Systems Command
Washington, D.C.

Mr. Carlson is Manager for Engineering Design of the Computer Supported Design Program, Naval Sea Systems Command. He began his career with the Department of the Navy at the Naval Ship Engineering Center in 1970. Prior to his current position, he served as ship arrangements task leader for a number of ship designs, Manager of the CASDAC Arrangement Subsystem, and Manager of the CSD Hull Design System.

Mr. Carlson received his BS and MS degrees in naval architecture and marine engineering from the University of Michigan. He is a member of SNAME, ASNE, and the U.S. Naval Institute.

## ABSTRACT

The Navy efforts in computer-aided ship design and construction have undergone a number of changes in the past two years. The history of these changes is presented, current efforts are defined, and future thrusts are outlined. This discussion includes the Computer Aided Ship Design and Construction (CASDAC) program, the Computer Supported Design program, the Manufacturing Technology program, and the Shipbuilding Technology program. The primary emphasis in describing current efforts and future thrusts is on NAVSEA's computer-aided ship design and the two-way interface of the Navy contract design package with the shipbuilder.

## History

The Navy program for applying CAD/CAM technology to ship design and construction has undergone a number of changes in the past fen years. To clarify these changes and their relationships, a summary of the history is required as shown in Figure 1.

The Naval Sea Systems Command established a computer-aided ship design group in 1952, one year after delivery of the first commercial computer. All of their efforts focused on applying computers to the ship design phases performed by NAVSEA. Based on the success of these efforts, NAVSEA established a program called CASDAC (Computer Aided Ship Design and Construction) in 1966. The objectives of CASDAC were to prove the feasibility of computer application, to verify the benefits, and to foster the use of computers to all phases of ship design and construction.

In 1980, this program was renamed the CAD/CAM Program. In 1981, the Navy split the program into two separate but coordinated programs. The "CAM" of "CAD/CAM" became part of a larger effort aimed at the private shipbuilding industry. That program is the shipbuilding Technology Program which in turn is a major segment of the Navy's Manufacturing Technology Program.

The "CAD" of CAD/CAM is now called the Computer Supported Design or CSD Program. The remainder of this paper will apply only to the CSD Program.

## Computer Supported Design Program

### Scope

The CSD Program addresses the need for and application of computer-aided design technology to the design phases performed by NAVSEA with the assistance of ship design firms. In the current NAVSEA ship design process, this includes all ship design phases through contract design as shown in Figure 2. This consists of two types of design; exploratory design and acquisition design. Exploratory design is aimed at defining future ship concepts and assessing the ship impact of developments in ship system technologies- As such, these design efforts are geared to supporting decisions in the development of technology as applied to future ships. Acquisition design is aimed at the design of ships for the Fleet in response to the needs of the Chief of Naval Operations. Acquisition design consists of four stages; feasibility studies, preliminary design, contract design, and detail design. Feasibility designs are executed in close coordination with the Office of the Chief of Naval Operations (CND) to define the required characteristics of each new ship class that meet the performance requirements and cost constraints.

Preliminary design develops the design to a level required to produce a budget quality cost estimate.

The purpose of contract design is to perform the engineering development of the preliminary design and to produce the specifications and drawings on which the shipbuilders can base their bids.

Following award of the shipbuilding contract, the Shipbuilder performs detail design and construction. Detail design completes the engineering of the ship and tailors the design to the construction facilities and practices of the shipyard. Detail design and construction are overlapped to speed delivery of the ship. The risk of parallel design and construction is significant. NAVSEA design practice has been of sufficiently high quality to make the risk sensible. Both the Navy and the Shipbuilder place great reliance upon the completeness and correctness of the NAVSEA Contract Design Package.

### Need

NAVSEA faces a number of challenges in performing ship design. These include:

* The need for improved engineering capability to design capable and affordable ships. Existing engineering techniques are *no* longer adequate for the complexity of today's naval ships and the constraints of design-to-cost.
* The need to respond to CND in a timely manner,
* The projected increase in ship design workload.
* NAVSEA’s manpower restrictions.

Given these CND requirements and *cons* traints, NAVSEA must substantially improve the quality and productivity of its ship

design capability. A major part of NAVSEA's attack of this *problem is* to enhance the technical capabilities of the ship design engineers with the computational and data management power of the computer.

## Objective

The objective of the Computer Supported Design (CSD) Program is to improve NAVSEA's ship design capability by providing a computer-based system of design tools. NAVSEA cannot perform ship design or fleet support today without the existing tools built by the CSD Program. With the increased demands of CND, a complete CSD Program is required. The CSD Program performs total life cycle management of the computer-based ship design system. This consists of the developments procurements and operational support of the computer programs, databases, and computer equipnent which form the CSD system. Particular attention is being placed on the design areas such as spacer weight, manning, and combat system performance that drive ship cost and performance.

## Current Efforts

The CSD Program has been conducting a major planning effort to define a computer-aided ship design system that meets all the needs of NAVSEA. The near term focus *is* on surface ship design to suit the workload projected by the Five Year Defense Plan, The longer range includes submarines, non-conventional ship types, and ships built to commercial standards.

To provide the total computer-aided ship design system needed by NAVSEA, the CSD Program addresses nine thrust areas:

* Architecture - The blueprint of the CSD system.

* Design Information - Development and maintenance of the central databases.

& Design Applications - Development and maintenance of the application programs for the individual design disciplines.

* Utilities - Development and maintenance of common applications and software libraries-

* Computer Systems - Acquisition and support of the required computer hardware.

* Facilities - Hodifications of NAVSEA facilities to handle CSD.

* Training - Training of users, management, and project personnel.

* Project Management - Management of the development and maintenance of CSD.

* Technology Transfer - The dissemination of CSD products.

Of primary interest are the design applications and design information areas. The design applications are divided into four engineering subsystems:

Ship Design - feasibility studies

Hull - Preliminary and contract design

Machinery - preliminary and contract design

Combat Systems - preliminary and contract design

CSD is not proposing the development of an automated system. The design engineer provides the core of the system using the computer as an aid in the design process. Organizational units retain control of their cognizant data through controlled access and release of their ship design data in a manner similar to drawing approval and release. The CSD concept must reflect both the NAVSEA organizational requirements and the technical requirements of a major computer based system.

Figure 3 illustrates the CSD system concept. The engineer identifies himself, the design to be worked on, and the task to be performed. If the engineer is validated, the appropriate application program is selected which, in turn, defines the required datasets. For the design requested, the appropriate datasets are gathered from the engineer's private datasets, released datasets from other engineers, or approved (baseline) datasets. The program is then executed and the results added as private datasets. If desired, the engineer can release the datasets for review by other engineers and management approval to become new baseline descriptions. The key feature of this concept is the lack of the single, massive, master database containing the total description of the ship from which everyone works. Given the engineering design process attuned to drawing issues, the multitude of designs generated, and hardware restrictions, the dispersed database better meets the needs of NAVSEA. At the same time, it allows a *more* evolutionary, incremental approach that makes use of existing programs.

Parallel with this planning efforts the development of individual application programs has continued. Two of these, HULSTRX and the Design File Manager, are described in separate IREAPS 82 papers. These programs plus HULGEN and HULDEF for hull form design and DEKOUT and GENARR for general arrangements form the ship geometry design package of CSD as shown in Figure 4.

In addition, current CSD efforts include the establishment of standards. The NASA IPAD RIM (Relational Information Manager) has been selected as the standard database management system for CSD and is currently being evaluated. A standard drafting system will

be selected in FY 83 as well as standard graphics interface package for application programs. A software development specification for CSD is being completed invoking FORTRAN 77 (ANSI X3.9-1978,full set). These standards form the basis for all future development.

One aspect of CSD that might be dropped is technology transfer. The CSD Program currently disseminates about 400 copies of programs per year to industry, universities, and other goverrment agencies. The dissemination of Navy computer programs is not essential to the objectives of the program. The ship design agents and shipyards that support NAVSEA acquisition design will be required to perform their tasks using CSD programs on CSD hardware. In view of the resources required for dissemination, this service to the marine industry is being critically reviewed by NAVSEA.

## Future Outlook

The future wil1 see the continued development of CSD applications and the other thrust areas. In keeping with the evolutionary approach of CSD, completion of each of these will make a small increment towards completion of the full CSD design capability.

However, the sun of these increments will mean that the entire contract design package wil1 be computer-generated. It is in the best interests of the Navy and the shipbuilding industry that this information be transferrable to the Shipbuilder in computer-sensible as we11 as hard-copy form. This is being done today for the Ship Specification. An increased exchange is currently being investigated for the DOG 51 as a result of producibility studies conducted by shipyards. The use of the Interim Geometry Exchange Specification (IGES) foras the leading candidate for an exchange format. An IGES interface wil1 be added to the NAVSEA in-house drafting system, IDS, in FY 83. There is also a need for the return of design information to NAVSEA for its review role during construction and "as-built" information to fleet support the thirty plus years of NAVSEA support of the ship.

## Conclusion

This paper has reviewed the history of the Navy's computer-aided ship design efforts9 summarized the current efforts, and highlighted future directions of the effort. It has also indicated where interfaces need to be addressed between the NAVSEA efforts and the private shipbuilding industry- NAVSEA is making progress on meeting the objectives of its computer-aided ship design program; to increase the productivity and excellence of its ship design organization.

# HISTORY

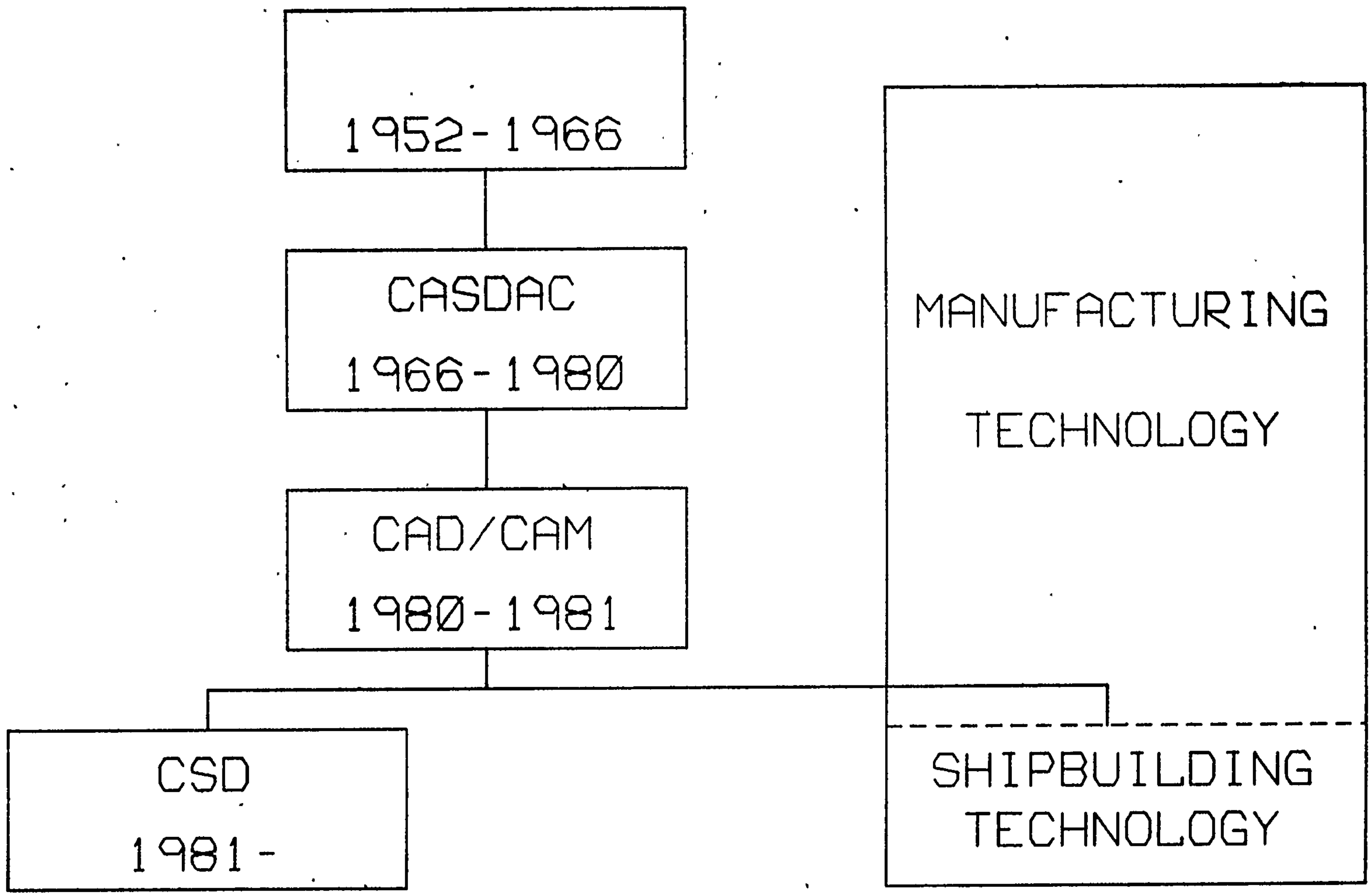


FIGURE 1 HISTORY

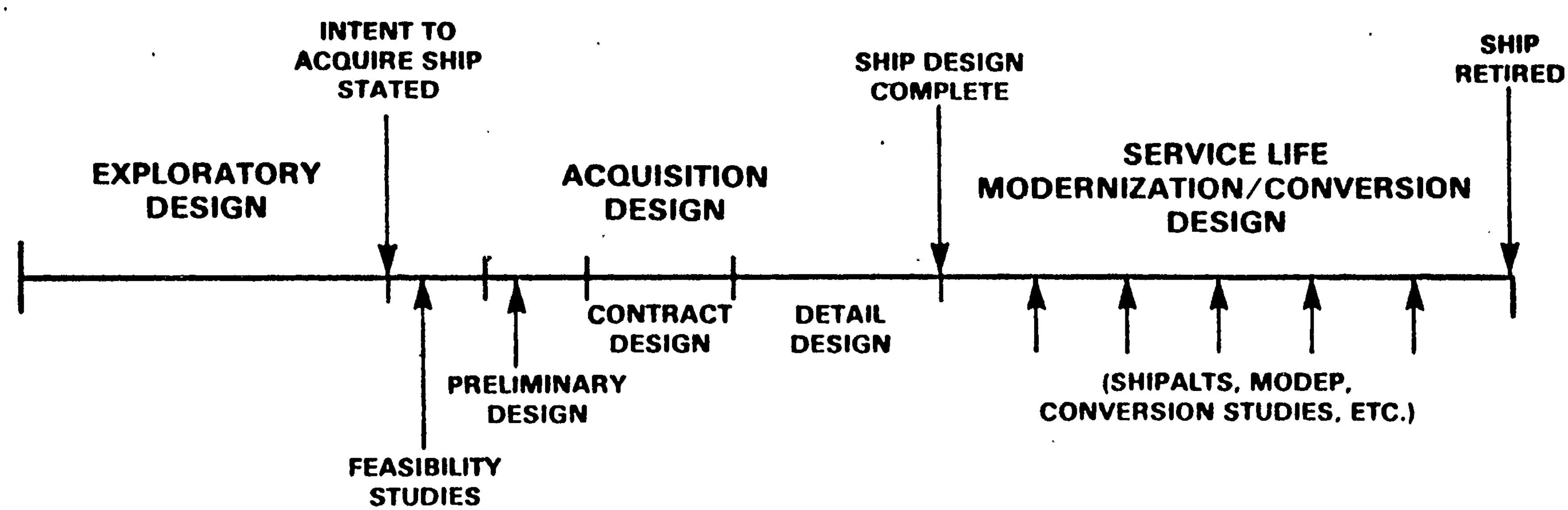


Figure 2 SHIP DESIGN PROCESS

# CSD SYSTEM CONCEPT

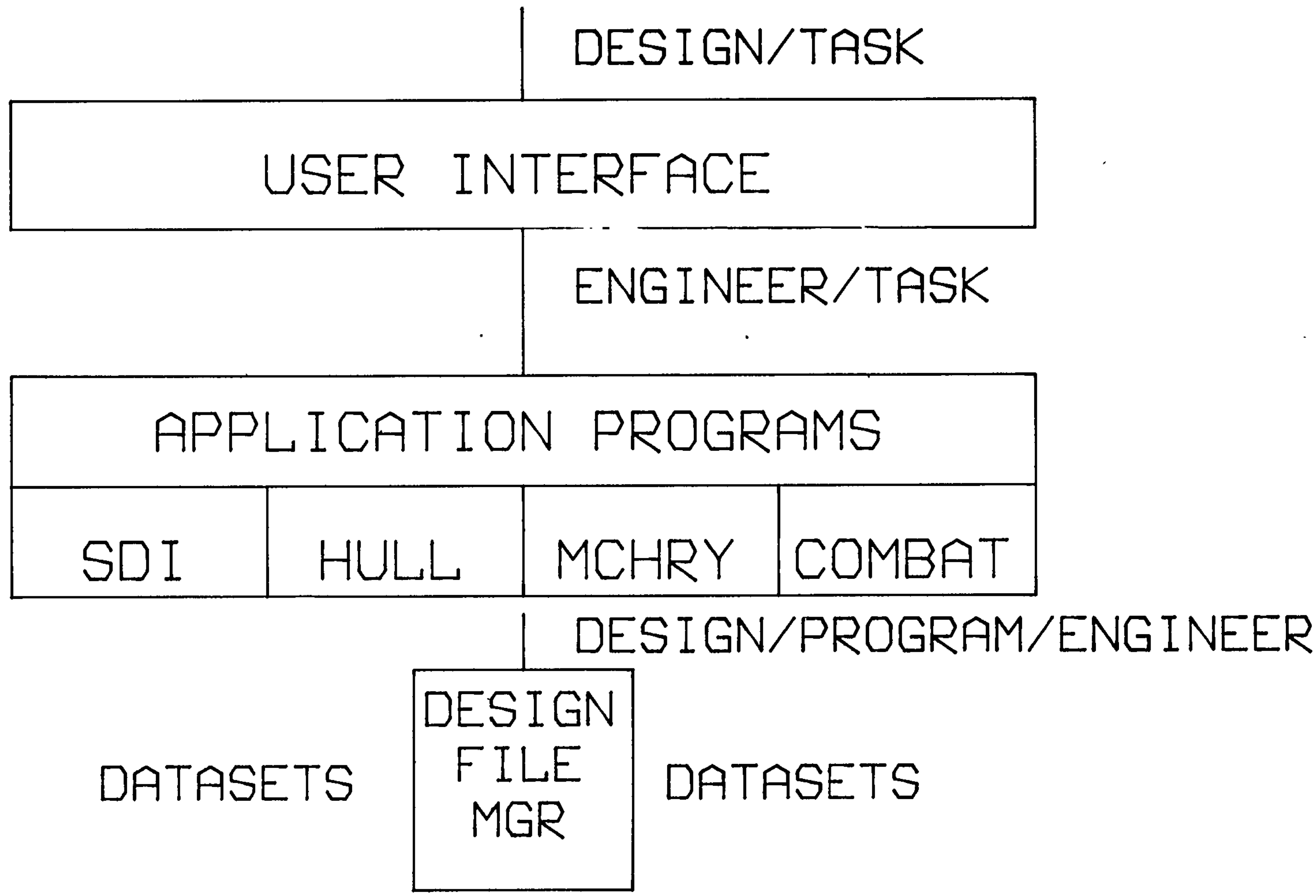


FIGURE 3 CSD SYSTEM CONCEPT

# SHIP CONFIGURATION DESIGN

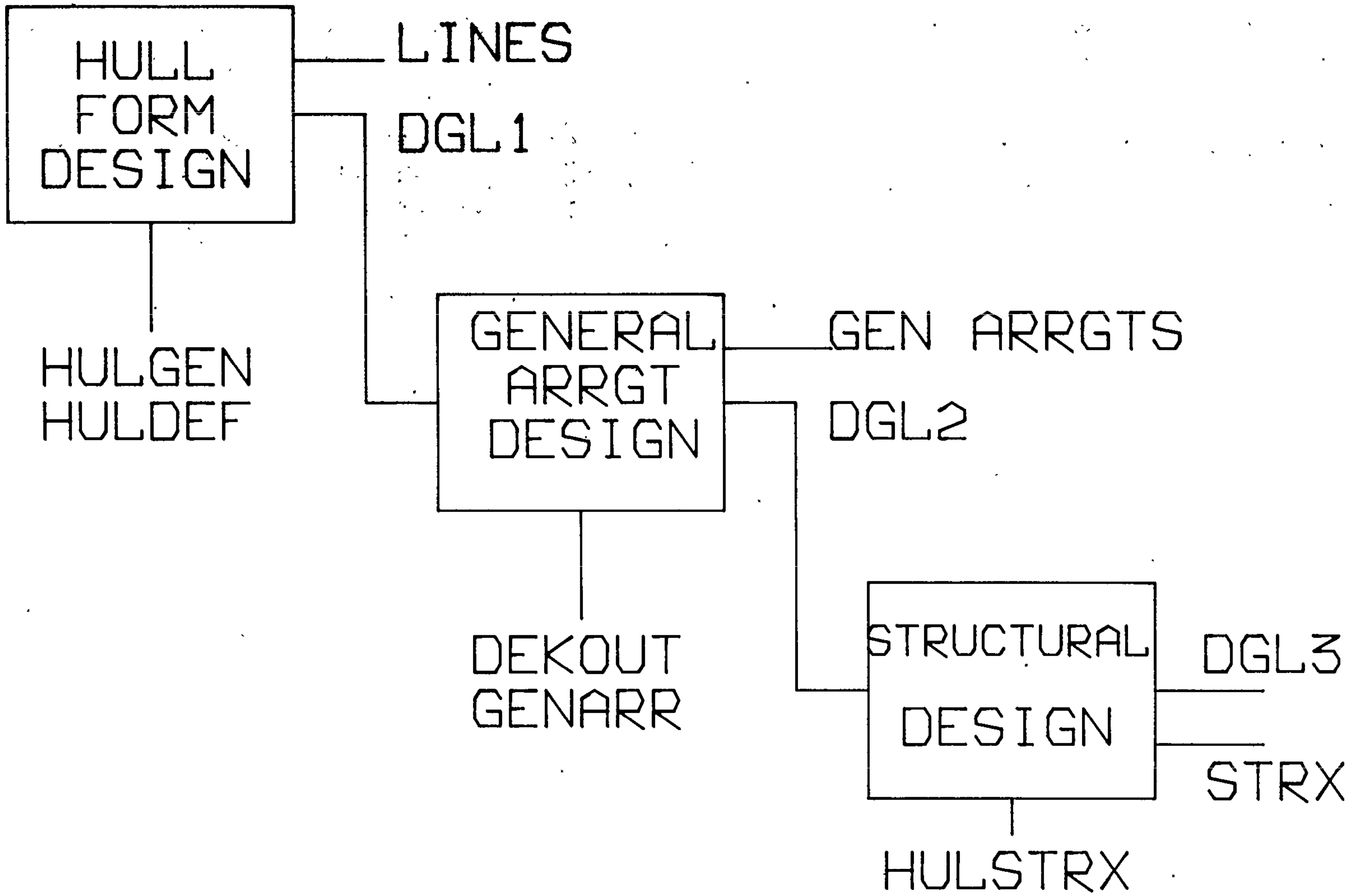


FIGURE 4 SHIP CONFIGURATION DESIGN

# PRODUCTIVITY IMPROVEMENT IN SHIPYARD STEEL FAERICATION THROUGH INTEGRATED MATERIAL HANDLING TECHNOLOGY

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TTS is a company specializing in custom-designed material handling and production systems for shipyards worldwide. Before joining TTS in early 1982, Mr. Draegebo was General Manager of New Construction at Halifax Industries' shipyard in Halifax, Nova Scotia, and prior to that he held several senior technical, production planning, and marketing positions with Davie Shipbuilding Limited in Quebec, Canada. Mr. Draegebo's early career in the Norwegian shipbuilding industry included three years as a consultant with Shipping Research Services of Oslo, Norway.

Mr. Draegbo is a graduate in naval architecture and marine engineering from the Technical University of Norway.

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Prior to 1979 when Mr. McConnell joined TTS as Vice President, he worked as a consultant in the field of shipyard management and facilities development. He has earlier managed the Program Planning and Manufacturing Engineering groups at Ingalls Shipbuilding, and was for several years associated with General Dynamic's Electric Boat Division.

Mr. McConnell has a BSME degree from Lehigh University and is a former member of the SNAME Ship Production Committee.

## ABSTRACT

A significant portion of shipyard steelwork can be mechanized through introduction of modern production line technology. The productivity improvements on such lines arise principally from more efficient material handling and a corresponding reduction of time lost between operations. Panel lines are undergoing exiting developments and are being installed even in very small shipyards. Efficient and affordable web line and beam line technology is now available but not yet adopted by shipyards in the United States.

## 1. INTRODUCTION

Before adressing how production lines and other in-process material handling applications impact shipyard productivity, it is interesting to explore which portions of the total shipbuilding effort we are dealing with.

As any student of shipbuilding productivity will know, recorded manhour expenditures and cost data are generally not published, and very little material is therefore available on this subject. Furthermore, differences in cost recording practises, etc., make inter-company comparison difficult even if figures are obtained.

It is therefore with some caution that the authors have analyzed manhour expenditure records from a sample of medium-sized shipyards, and are presenting judiciously averaged percentages in figure 1. The data relate to 25 - 40,000 tdw product carriers and bulk carriers, plus to large offshore supply vessels. The shipyards in question are "conventional", i.e. non-mechanized. Steelwork (accounting for approximately 45% of the total "direct" manhours) includes all structural steel with deckhouses and superstructure but excludes outfit steel and castings.

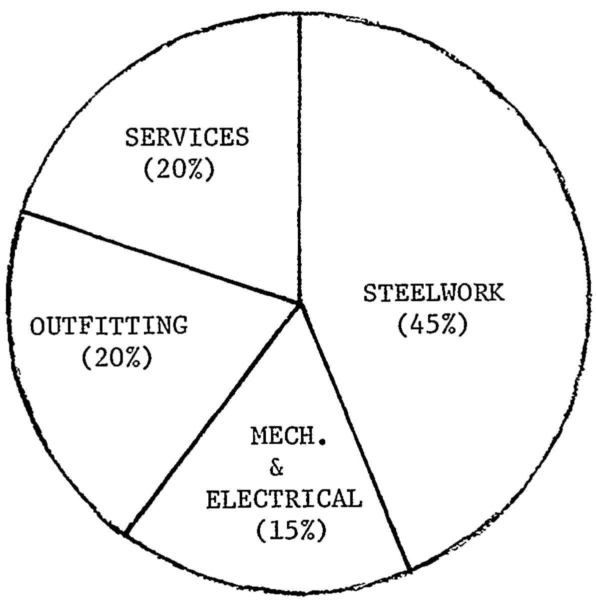


Fig. 1. Break-down of Total Ship Production Manhours

A further break-down of the steelwork manhours is indicated in figure 2. Based on our sample figures, we find that approximately 5% of the steelwork hours are spent on marking and cutting (prior to assembly), 30% on welding, and the remaining 65% on platework (i.e. fitting and tack welding) plus miscellaneous activities such as frame bending, rolling, pressing, grinding, stockyard manipulation, etc.

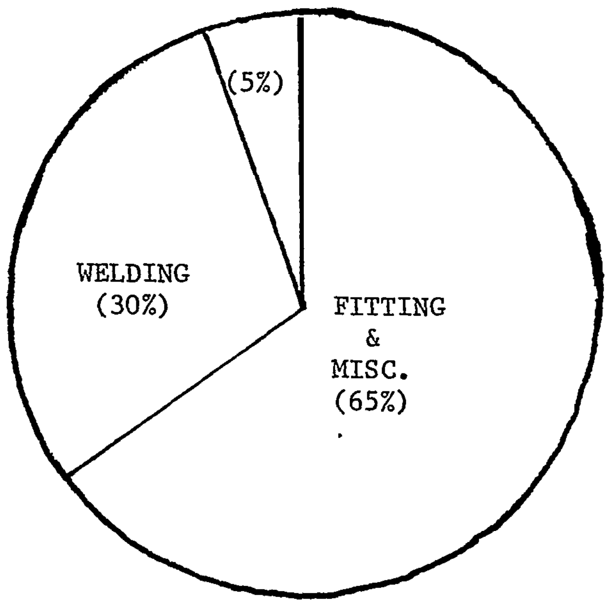


Fig. 2. Break-down of Steelwork Manhours

We may throw further light on the subject by refering to research done by the Norwegian Ship Research Institute in cooperation with a group of shipyards (ref. 1). After analyzing several sizes and types of vessels, the Institute established that 40 - 75% of the total steelweight lends itself to mechanized line production. The portion naturally depends on the type of ship and can be significantly increased by designing the ship to suit the facilities.

Figure 3 introduces a different and more controversial breakdown of the steelwork manhours mentioned above. We postulate that in an "average" shipyard less than 50% of the steelwork manhours are actually spent on bona fide production activities, with the balance going mainly to in-process transportation and operator waiting time (including time spent on moving and mobilizing people, transporting tools, bringing material to and from the various worksites, waiting for cranes, preparing fixtures, waiting for instructions, interference between activities, etc.).

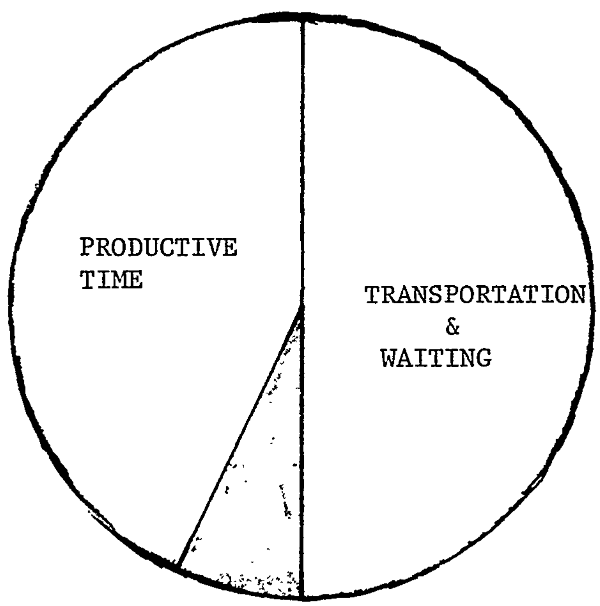


**Fig. 3.** Steelwork Manhours shown as Productive and Unproductive Time with a "Grey Area".

This situation is not evident from conventional cost records. A tradesman's time is routinely charged against a job number and sometimes also against a unit or zone number as time worked whether he waits in line at the tool crib, walks from one jobsite to another, waits for a crane, or actually works.

Normally only time lost due to significant and lengthy interruptions (like power failure) would be recorded as waiting time. Except for trades like welders (where arc time can be accurately and impartially measured) getting a true picture of the productive work time requires the use of time study methods.

As our abovementioned postulation (that less than 50% of the steelwork manhours are spent productively) is not based on a body of scientific data, we invite the audience's comments on this matter during the discussion period. We would like to mention, however, that production staff at numerous shipyards almost unanimously have accepted our postulation and in fact in many instances have pointed out that the situation is worse than we claim.

The balance of this paper analyzes the application of production line material handling technology to efficiently bring together material, tools and people to reduce the unproductive time described above.

## 2. TRADITIONAL SHIPYARD PRODUCTION LINES

The most widely adopted application of production line technology within the shipbuilding industry is in-line fabrication of stiffened steel panels. As will be discussed later, most existing panel lines are not primarily improving the production processes per se, but are tremendously reducing unproductive time between these processes by rationalizing the handling and transportation of material between organized work stations.

In principle, a panel production line consists of a floor-mounted conveyor system or roller bed along which is arranged a number of work stations specially designed, equipped and manned for the individual operations required to produce a stiffened panel. The width of the floor-mounted roller bed is normally equal to the widest panel which will be made on the line (normally 30 - 60 ft.), and the length of the line (normally 150 - 500 ft.) depends on the number of work stations and the degree to which the panels are completed on the line.

The conveyor system or roller bed is arranged with suitable drive mechanisms to advance the panels from one work station to the next, and normally equipment for mechanically manipulating, aligning and turning the panels are built into the roller bed.

Typical work stations are:

- aligning, fitting and tack welding of plate butts
- butt welding (normally with submerged arc equipment)
- turn-over of plate blankets (except for lines using one-side butt welding equipment)
- marking and edge trimming
- stiffener fitting and tacking
- stiffener fillet welding
- web fitting and tacking
- web welding
- preoutfitting.

No panel lines will have all these stations, and some stations may be arranged for more than one function depending on product mix and capacity considerations. Obviously, the more complete the panel can be made on a panel line the more efficient the total production will be.

Panel production lines have been around for a long time, in fact, one of the earlier US patents within this area was issued to Sun Shipbuilding of Pennsylvania in 1932. However, widespread introduction of panel lines generally took place in the 1960's as shipyards, particularly in Europe and Japan, were constructed or expanded to meet the steadily increasing demand for larger and larger oil tankers.

The three or four standard makes of panel lines which competed commercially to meet this demand all represented major improvements from the conventional assembly techniques. They provided the yards with well-organized work stations and a superior material flow with much less dependence of overhead cranes.

Generally, the panel lines of the 60's and early 70's were characterized by:

- massive structures with fixed work stations
- two-side butt welding of plates, even though some one-side welding methods were introduced
- stiffener infeed from the side, generally through elaborate bridge structures with hydraulic clamping devices
- no special tools for web fitting and welding
- relatively high cost.

Some of these characteristics may today seem less than desirable, but for the emerging builders of VLCC's and ULCC's the new technology was ideal and contributed significantly to the dramatic increase in productivity of building of large tankers and bulk carriers. However, panel lines were generally not introduced in other than the largest yards, and were in fact considered suitable only for high volume production.

## 3. "STATE OF THE ART" OF THE PANEL LINE TECHNOLOGY

The dramatic change of the shipbuilding scene in the mid-1970's had a fundamental impact on the panel line technology. Generally, the suppliers of panel lines were faced with the following situation:

- an abrupt halt in the development of new large shipyards (with a few exceptions in places like South Korea and Brazil).
- a realization in the industry that the period of building very large ships had temporarily come to an end, and that future shipbuilding orders would probably not be for long series of sister ships
- several shipyards switched their attention to the off-shore industry or concentrated on building special type vessels.

While these difficult times for the shipbuilding industry meant equally difficult times for the panel line suppliers, they also presented a tremendous opportunity and challenge: Medium-sized and small shipyards had to improve their productivity to survive in a shrinking market where they were now suddenly competing with the large yards. To do so, they needed to mechanize their material flow and production methods.

In response to these needs, the panel line technology has been developed further over the last few years, in the following directions:

- much more flexible equipment, in two respects:
  - i) adaptable to existing buildings (previously this consideration was less important, as most panel shops were designed around a new panel line)
  - ii) adaptable to a wide range of vessels
- lower acquisition and installation cost
- higher productivity.

Technically, these developments have been achieved through the following means:

- more common use of one-side butt welding. Not having to turn the panels for back welding reduces the length of the panel line and eliminates the need for a special panel turning crane (which requires a high bay locally over the turning station). It also eliminates time-consuming back-gouging and back welding processes.
- more flexible work stations allowing an operation to take place in several locations along the line

- in-line stiffener infeed
- equipment for fitting and welding webs and minor bulkheads is incorporated into the line
- the panel line is to a greater extent integrated into the upstream and downstream material flow
- adaptation of mobile jigs allowing curved panels (with sweep and camber) to be assembled on a panel line
- special panel lines developed for high-volume barge yards.

These developments, together with the competitive forces in the market place, have seen panel lines introduced into many medium sized and small shipyards over the last few years. In fact, the authors' company has installed *a* panel line in a shipyard with only 60 employees and an annual production of about 1.5 small vessels (trawlers or ferries).

## 4. CURRENT DEVELOPMENTS

"Survival of the fittest" means higher productivity, so present developments of the panel line technology is concentrated on even further reductions of the numbers of operators needed to produce a panel. Some examples:

- development of *a* one-man-operated one-side welding station where advanced fixturing devices eliminate the need for fitting and tacking of the butts prior to welding
- development of a fully automatic one-side butt welding station with unmanned plate infeed and outfeed. So far, this equipment is designed for non-code welding. Continuous through-the-arc welding parameter control equipment now becoming available may eliminate the need for constant operator presence for high quality shipyard butt welding as well.
- use of robots on the panel line.

## 5. OTHER PRODUCTION LINE APPLICATIQNS

While panel lines represent the most accepted way of mechanizing shipyard steel production, the return on invested capital is probably even greater for beam (shape) lines and web lines, even though these installations are less known, particularly in this country.

In November of 1981, MarAd released an excellent report on a beam-line feasibility study undertaken in cooperation with Avondale Shipyards (Ref. 2). The report concludes that proven beam-line technology is available today for any US shipyard willing to improve productivity and it predicts very impressive savings compared with present manual methods.

As with panel lines, the principle behind both web lines and beam lines is to eliminate costly transportation and waiting time through introduction of rational material handling technology. The work pieces are brought to well-designed work stations, and the operators and their equipment remain stationary.

To illustrate what a modern beam line can do, we can mention that at a medium-sized shipyard (about 20,000 tons of steel a year), it reduced the number of workers transporting, marking and cutting shapes from 17 to 5, principally through mechanization of the shape infeed and outfeed process. However, some of the savings were also obtained in the production process itself by arranging the burning tables for cutting of up to four shapes at the same time with a single-operator burning machine. Marking of the shapes *was* completely eliminated (except identification marking) by introducing a digital indexing system for positioning of the burning torches. See figure 4.

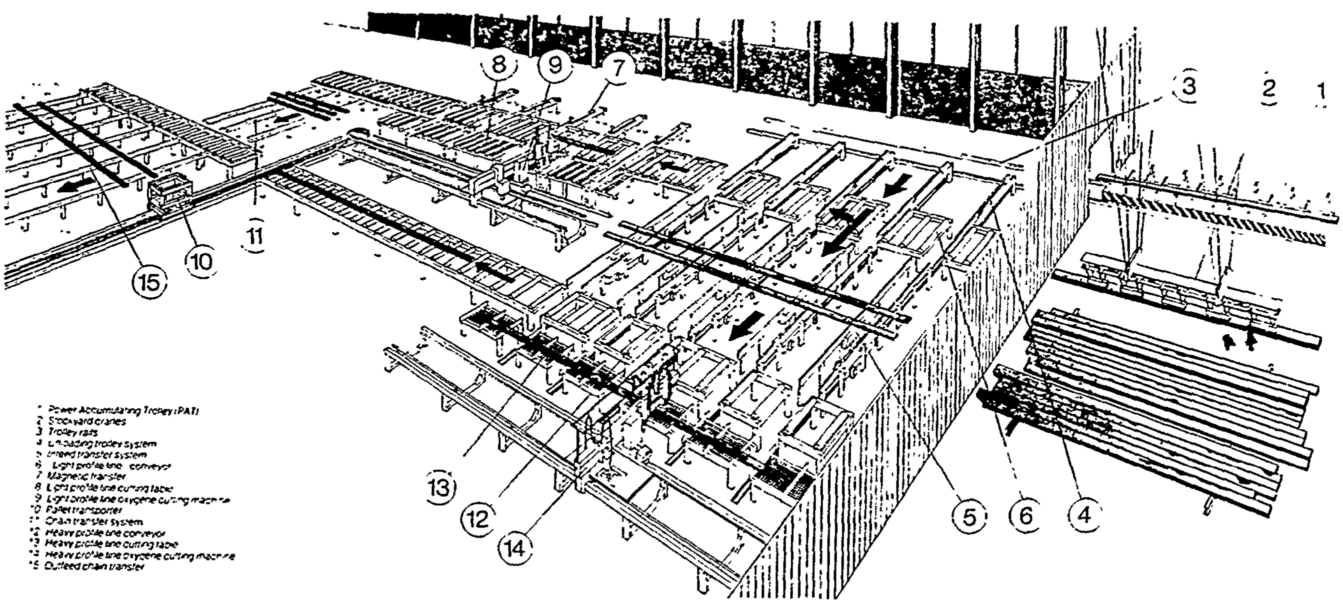


**Fig. 4. Schematic View of the Beam Line Installation at the Horten Yard in Norway.**

It is also worth noting that the few remaining operators were working under much more pleasant and safer conditions than previously, and that valuable shop space was released for other production.

The authors' organization is currently working with a US robot manufacturing company to develop *a* robot-operated beam line with plasma cutting equipment for a major East Coast shipyard. This project will further enhance the beam line technology, and we look forward to be able to report on the results of this development to the shipbuilding community in a not too distant future.

## 6. A SYSTEMS APPROACH

To maximize the benefit of any shipyard production line, it is important to regard the line as an integrated part of the total production system. The yard should carefully study its overall production capabilities to ensure that the selected production line equipment is compatible with other equipment. For example, one-side welding techniques are generally sensitive to the plate edge quality and require the use of an N/C burning machine or a high-quality flame planer to achieve the required results. Thus, a yard without adequate facilities for achieving good plate edge quality should opt for a less sophisticated welding technique.

For panel lines, it is also important to ensure that downstream transportation facilities are adequate to allow the fullest extent of panel assembly and possibly pre-outfitting prior to moving to the block assembly or hull erection areas.

The principle of integration of the production lines into the total yard system also.extends to technical information and the production planning and control routines. For instance, successful operation of a panel line requires a detailed plan for panel sequencing and manpower loading per work station, and of *course* subsidiary schedules for plate cutting, stiffener preparation, etc. Furthermore, technical information should be presented in a form suitable for the operators on the individual work stations. This latter task is easily achieved in yards where ad hoc information can be extracted from *a* hull data base whereafter dimensions and instructions needed by the respective operators can be added.

## 7. CONCLUSIONS

In the introduction of this paper, the relative importance of steelwork in the total cost of certain commercial vessels was discussed. The production line methods described in the foregoing can to varying degrees be applied to the total steelwork, but in all instances the savings potential is significant.

With a modem panel line, a theoretic productivity of 1.5 - 2 manhours/ton is normal (for fitting and completely welding an average panel with stiffeners and webs). The degree to which this target productivity is actually realized depends largely on the ability of the individual organizations to fully gear their production routines, technical information and planning methods to the new hardware. As with any new equipment and methods, there are success stories and also less successful implementations.

The actual savings compared to conventional methods vary from user to user, but as an indication it can be predicted that a panel line installation will pay for itself in about a year provided it can operate steady on a one-shift basis. Savings due to web lines and beam lines are even more difficult to measure. However, the MarAd report (ref. 2) mentioned previously projects a labor savings of 78.3% through shipyard application of a beam line.

However, most impressive is the fact that productivity improvements arising out of the described production line technologies are not due to anyone working harder and only partly due to more effective process equipment. Basically, the benefits come from common-sense material flow which allows each operator to function effectively with a minimum of time lost for reasons beyond his control.

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# IMPROVING SHIPYARD PRODUCTIVITY BY SUBCONTRACTING MATERIAL AND LABOR WITHIN SHIPYARDS

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## ABSTRACT

It can be taken as true that an organization which specializes in one area produces at lesser cost than an organization which, in one plant, produces and assembles in substantially different areas. Shipyards which manufacture and assemble many different products recognize the advantages of specialization; they try to purchase materials and equipment in as finished form as available for further assembly and installation. In some areas shipyards go further and subcontract the installation of material directly into ships.

The thesis proposed here is that the productivity of U.S. shipyards would be increased and ships would cost less if a deliberate policy of extensive subcontracting of material and its installation labor within shipyards were adopted. In time, shipyard staff would become primarily specialized efficient organizations which coordinate the work of specialized, independent contractors. The organizations would be the same in principle as those which have developed for most large, land-based construction.

The discussion explores the promise of this change from present practice. How would it apply to traditional and newer preoutfitted modular construction and its effect on the labor force of shipyards? Some of the discussion is based on the author's many years of experience working for a company which was a subcontractor for material and labor within large and small shipyards in the United States.

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Discussions I had on this subject with Mr. John J. McGowan, Chief, Division of Cost Estimates, U. S. Maritime Adminstration, helped define my views. I benefited from his experience and insight.

## INTRODUCTION

### REASONS FOR SUBCONTRACTING

A shipyard subcontracts when it assigns some portion of its contract effort to another firm without giving up its responsibility for the work subcontracted. It is a contract secondary to the prime contract between yard and owner. The term is generally understood to apply when the labor component is a significant fraction of the value of the secondary contract. In this discussion the term is used to include the purchase of any ship components which a yard with varied production facilities is capable of assembling or installing itself. Thus, I will depart from the restrictions of the title to include as subcontracts purchase of ship components which require a large labor component. Examples of subcontracts are: bitts and chocks, a skid-mounted pre-piped refrigeration unit, or services to furnish material and labor to install deck covering on a ship. Also, the discussion applies principally to those yards which could do that which they subcontract. Thus small yards are excluded.

Another way to look at subcontracting is that it is the "buy" decision resulting from a "make" or "buy" analysis. The considerations leading to the "buy" decision would have included:

a. The parts or services would be acquired at less cost than the total cost of yard labor and overhead applied to the purchase.

b. Manufacturing facilities are not available or facilities are committed to other work.

C. Manpower is insufficient or committed to other work.

d. The work is new and the yard has no experience with it.

e. The work is expected to be a one time effort so that learning and tooling is not justified.

f. The work is not related to building a ship. Addition of a new building or installation of specialized equipment are examples.

g. Other reasons, some of which are evident by naming some equipment or parts: electrical equipment, electronics equipment, and fasteners. Why these are not made would be answered by the observation that "the yard is in the business of building ships, not parts."

The first of the foregoing factors is the only one for which a serious make or buy decision is debated. The other factors virtually dictate "buy."

I believe that there is another reason behind each of the stated reasons, and that is that subcontracting increases shipyard productivity. That underlying reason is probably rarely expressed or explored. The purpose of this discussion is to do so.

## DEFINITIONS OF PRODUCTIVITY

Two definitions are needed:

a. Productivity is defined by the ratio, output per man hour. One method is more productive than another if more output results from the same number of man hours, or if fewer man hours are required for the same output.

b. Productivity is equivalent to efficiency, and can be defined as the ratio of dollars:

$$\text{Productivity} = \text{efficiency} = \frac{\text{output dollars}}{\text{input dollars}}$$

$$= \frac{\text{profit}}{\text{material} + \text{labor} + \text{overhead}}$$

In the foregoing ratio, yard profit is that anticipated or targeted. It could be that for a single contract or for the total yard operations per year. The denominator is the total of expenditures anticipated for the contract or year. If this total can be reduced through another method of operation then productivity is increased.

# OBSERVATIONS AND PREMISES

## OBSERVATIONS

Some general observations about our common experience are in order. Two premises which stem from these observations will then be stated.

a. The first observation comes from the nonresidential construction industry, specifically that which builds office buildings of thirty or more stories. The builder is a general contractor who contracts virtually all the input to complete the structure. Beginning with the site survey and proceeding toward completion he organizes and schedules the work of different subcontractors who separately, but in parallel and series do: excavation, foundations, concrete, structural steel, electrical work, heating and air-conditioning, plumbing, glazing, and waterproofing. When the building is almost complete, still other specialists take over: interior partitions, painting, flooring, office layout, draperies, locksmiths, even sign painters. Then still other specialists move in: rental agents, employment agencies, building managers, energy managers, cleaning services. Is a ship any less complex than a building, not to benefit from specialists?

b. Below is a list of items which have been subcontracted by yards. Most yards have the organization and plant to do some of these items but chose not to.

- Engineering services
- Computerized lofting and plate layout
- Heavy lift services
- Insulation, hull, machinery, and piping
- Joiner work, installation aboard ship
- Joiner work, completely outfitted modular staterooms
- Completely outfitted deck houses
- RO-RO gear of all kinds
- Hatch covers
- Large hull steel subassemblies made in one yard and carried by barge over long distances
- Tank blasting and painting.

C. The advantages of specialization by yards and organizations within the shipbuilding industry are evident in the appearance of yards which concentrate on large ocean barges, those which specialize in tugs and offshore boats, and those which specialize in drilling rigs. If they have appeared there must have been economic justification for them.

d. My own experience working for an organization which was a subcontractor to the shipbuilding industry has been favorable. Eastern Cold Storage Insulation Company subcontracted materials and labor in the areas of insulation, joiner work, and related materials of all kinds for commercial and naval ships in many shipyards of the United States. I came away with the conviction, stemming from long intensive experience that our work contributed to the productivity of each yard from which we received contracts.

A last general observation is important The estimate for aeshipbuilding contract predicts the material and labor costs and profit expected for the contract. All the estimators agree that material costs are much more accurately predicted than labor costs. At the end of a shipbuilding contract estimated versus actual costs are compared. It is almost always found that through all the rocky road of actual construction estimated material costs have been pretty close to target. Labor costs, on the contrary, have been too frequently underestimated. Since subcontracts are material their usefulness is evident.

PREMISES

From these observations two premises follow. The first relates to the first definition of productivity and reflects the experience of all of us outside as well as inside the shipbuilding industry. Indeed it is not a premise but a truism since our society is so organized: Specialists are more efficient, that is more productive than non-specialists. For a given number of hours they will produce more.

The second premise relates to the second definition and is the one to be discussed in the balance of this paper: The productivity of the relatively large shipyards which build a variety of ships can be increased if they subcontract to a greater degree than they do now. Subcontracting will reduce their total expenditures for material and labor and overhead and therefore increase their productivity. In other words, as the components of the denominator become more material dollars and fewer labor and overhead dollars, shipyard productivity will increase.

## EXAMINATION OF THE PREMISES

ESTIMATE FOR A 40,000 DWT BULK CARRIER

We start by examining part of an estimate for a 40,000 DWT bulk carrier built in the United States. It is not an actual estimate but one which is assumed and is believed to be'

## 40,000 DWT Bulk Carrier

Principal Direct Material and Labor Costs

Part 1 - Material Purchased Substantially Assembled and Subcontracted Material

| MARAD Cost Group | Description | Material Dollars 000's | Labor Hours 000's | Labor Dollars (Hrs.x$25) 000's | Labor Dollars as Percent Material Dollars |
|---|---|---|---|---|---|
| 5 | Hatch Covers | $ 1,675 | .5 | $ 13 | 1 |
| 25 | Main Engine | 6,000 | 6.0 | 150 | 2 |
| 21 | Cargo Cranes | 2,575 | 3.0 | 75 | 3 |
| 28 | Steam Generating Plant | 575 | 1.0 | 25 | 4 |
| 7 | Anchors and Chains | 400 | .8 | 20 | 5 |
| 14 | Windlasses, Steering Gear | 725 | 3.0 | 75 | 10 |
| 8 | Lifesaving Equipment | 200 | 1.0 | 25 | 13 |
| 10 | Joiner Work | 1,700 | 10.0 | 250 | 15 |
| 39 | Central Machinery Control | 500 | 3.0 | 75 | 15 |
| 23 | Radio and Electronics | 825 | 5.0 | 125 | 15 |
| 37 | Machinery Space Outfit | 75 | .6 | 15 | 20 |
| 11 | Deck Coverings | 75 | .6 | 15 | 20 |
| 17 | Refrigeration Systems | 150 | 2.5 | 63 | 42 |
| 26 | Shafting, Propeller | 675 | 12.0 | 300 | 44 |
| 33 | Distilling Unit | 75 | 1.5 | 38 | 58 |
| 36 | Compressed Air and Gas | 225 | 6.0 | 150 | 67 |
| | Subtotal Group 1 | $16,450 | 56.5 | $ 1,412 | |
| | Percent of Total | 56 | | 6 | |
| | **Part 2 - Other Material and Labor** | | | | |
| 29 | Fuel Oil Service | $ 275 | 1.5 | $ 38 | 14 |
| 34 | Sea Water System | 350 | 3.5 | 88 | 25 |
| 35 | Fresh Water System | 110 | 1.5 | 38 | 34 |
| 32 | Lube Oil System | 375 | 8.0 | 200 | 53 |
| 22 | Electricity | 2,250 | 75.0 | 1,875 | 83 |
| 18/20 | Hull Piping Systems | 1,725 | 75.0 | 1,875 | 109 |
| 12 | Utility Outfit | 150 | 7.0 | 175 | 117 |
| 30 | Steam and Exhaust Systems | 150 | 8.5 | 213 | 142 |
| 1 | Steel | 6,325 | 475.0 | 11,875 | 188 |
| 4 | Hull Fittings | 200 | 18.0 | 450 | 225 |
| 27 | Air Intake - Exhaust Uptake | 50 | 6.0 | 150 | 300 |
| 9 | Masts and Rigging | 25 | 3.0 | 75 | 300 |
| 24 | Painting | 725 | 100.0 | 2,500 | 345 |
| 15 | Air Conditioning | 200 | 28.0 | 700 | 350 |
| 40 | Machinery Space Ventilation | 125 | 20.0 | 500 | 400 |
| 3 | Staging, Shoring, Cribbing | 125 | 30.0 | 750 | 600 |
| 38 | Machinery Space Access | 25 | 10.0 | 250 | 1,000 |
| | Subtotal Group 2 | $13,185 | 870.0 | $21,750 | |
| | Percent of Total | 44 | | 94 | |
| | Total Direct Cost | $29,635 | 926.5 | $23,162 | |
| | Total Percent | 100 | | 100 | |

representative of such ships and other ship types built in the kind of yards we are discussing.

Table I shows the principal direct material dollars and labor plus overhead costs in hours and dollars (at $25 per hour) required to build the ship. Small items have been omitted. The item numbers and corresponding description identify MARAD cost groups. All the groups are then divided, for this analysis, into two parts. Part 1 consists of material purchased substantially assembled and of subcontracted material. Part 2 consists of all other material. Together both parts include virtually all the items which are physically present on the completed ship. Supporting costs such as crane services, cleaning services, launching, docking, trials, insurance and fees are not shown. For such support, as a percent of the total of Parts 1 and 2, material costs would be about 5 percent of the direct material, and labor costs about 25 percent of the direct labor. Engineering costs would be about 11 percent of the first ship costs, if the design were new.

Within each Part the items are listed in the order of the lowest ratio of the number of labor dollars expended in the shipyard to install the number of material dollars purchased. The lower the ratio the less the shipyard labor input. This bears on the premise expressed above, fewer labor and overhead dollars for the denominator of the productivity ratio.

The division between Parts 1 and 2 of the Table is not part of the MARAD cost system but has been made only for this paper.

A condensed version of Table I is:

| | | Dollars | |
|---|---|---|---|
| Part | Description | Material | Labor and Overhead |
| 1 | Material purchased substantially assembled and subcontracted material | $16,500,000 | $ 1,412,000 |
| 2 | Other material | $13,185,000 | $21,750,000 |
| | Total | $29,685,000 | $23,162,000 |

| | | Percentages | |
|---|---|---|---|
| Part | Description | Material | Labor and Overhead |
| 1 | Material purchased substantially assembled and subcontracted material | 56% | 6% |
| 2 | Other material | 44% | 94% |
| | Total | 100% | 100% |

The second version is to be particularly studied. Only 6 percent of the direct labor and overhead needed to build the ship is expended on items purchased substantially assembled or subcontracted. 94 percent of the labor is expended on items acquired in pieces. The value of the material dollars is equally significant. Six percent of labor installs 56 percent of the material cost of the ship, while 94 percent of the labor cost is expended on 44 percent of the material cost.

The impact of the foregoing percentages appears persuasive. Materials in Part 1 require minimum yard labor. Would it not follow that as materials are moved from Part 2 to the classification of those in Part 1, "Purchased substantially assembled and subcontracted material" that productivity of shipyards would increase? We will examine the ramifications of that conclusion.

ADVANTAGES OF SUBCONTRACTING

The advantages of subcontracting material and labor both outside and inside the yard include:

Uncertain future labor dollars are converted into fairly predictable material dollars. This means that the probability of achieving the expected profit on the contract is significantly increased.

b. The task of running the labor force is reduced. To get an idea of the advantages consider a yard with the same dollar volume of business but with say one-quarter to one-half less workforce to handle.

c. Less investment in capital equipment will be needed.

d. Less material inventory will be needed.

e. Fewer purchase orders need to be issued and tracked.

f. Since subcontractors are specialists, improved quality of output can be reasonably expected and there is increased likelihood that yard schedules will be met.

g. There is more stability of yard employment. Typical conditions where there is work for the steel shop but little for the outfitting shops, or later, when the outfitting shops are busy but there is no work for the steel shops would be lessened.

h. Subcontracting, if sufficiently implemented, will make yards better prepared to change with the times. It will be easier to build new ship types and more diverse ships may be contracted for because the yard will be less committed to fixed plant and assembly skills. Good organizational and scheduling skills which it will have specialized in will provide the necessary flexibility to take advantage of new opportunities.

## OBSTACLES AND DISADVANTAGES OF SUBCONTRACTING

There are valid arguments against subcontracting.

a. Shipyards already are specialists. This argument impinges directly on the premise that subcontracting is taking advantage of specialization and results in less labor to build a ship. The argument continues that the yards under discussion already are specialists and that the degree of specialization they represent is about as fine as practicable. After all, most shipyards produce mostly ships although they could produce railroad cars.

b. The argument allied to the one above goes thus: The shipyards are now composed of a group of specialists whose work is organized and scheduled centrally. This group of specialist departments, structural, electrical, pipe, paint, machinists, and others are run by very competent staffs who are accustomed to working with each other. Together, for a given task they can, it is asserted, produce with fewer labor hours than any group of subcontractors. It may be said that they represent the economic optimum of each specific yard after each has come to the stage of subcontracting represented by the material of Part 1 of the estimate discussed above. This is a strong argument and expresses reality for each yard. Its departments and shops are specialists, staffed at the management levels with men of long, hands-on experience building ships. They are dedicated to their work and to the shipyards which employ them.

C. To consider the foregoing argument, take one example. Table 1 shows that Cost Group 1, Steel, totals 475,000 hours to fabricate, assemble, erect, and weld the hull and superstructure. Now consider that production rates for the same

type of steel work for multiple ships vary among yards from 50 to 90 man hours per ton. If a yard which produces at say 70 hours per ton were to buy subassemblies from one producing at say 55 hours it would save 20 percent of its direct steel labor. In this instance a substantial savings of 100,000 direct hours and 125,000 direct plus support hours would result. Thus, despite yard departments being specialized they are not necessarily as productive, or as efficient, as the work permits. One reason is that the investment in tooling for the same shops varies among yards. Another is that shipyard departments are not independent, their efficiencies being affected by other departments. Still another reason is that many yard departments work intermittenly at low capacity rather than continuously at high capacity.

d. Yards have substantial investment in material handling equipment, drydocks, piers, storage and administration buildings, and machinery such as welding equipment. In addition there is a substantial investment in shop buildings and the tools housed in them. In total, these investments may well weigh against subcontracting, but they should be viewed individually. All the facilities except shop buildings and tools would probably still be needed even in an extensive subcontracting program. They would continue to be carried in the overhead account. Shop buildings and tools would continue to be used but less intensively and could be accounted for on a depreciated basis rather than on a replacement cost basis. One method of taking the investment in existing plant into account when deciding on subcontracting is given below.

Union agreements usually stipulate that work within the yard may not be subcontracted without concurrence by the unions. In the past unions have not objected to "Furnish and Supervise*' subcontracts. In such subcontracts which are fixed in amount for both material and labor the subcontractor draws his labor, except for supervision, from the yard force which remains on the yard payroll. Hours in excess of an agreed amount are charged to the subcontractor. This arrangement has been satisfactory to both subcontractor and yard. The disadvantage that the workforce is not wholly responsible to the subcontractor is compensated by the subcontractor drawing only the number of men he needs and, under the informal understandings prevalent in yards, choosing only the men he wants.

f. Once a contract has been signed with a subcontractor the yard becomes dependent on his performance. If the subcontractor fails to deliver the yard has to seek a substitute or be prepared to do the work itself. However, the record of subcontract performance in the shipbuilding industry, when reputable subcontractors were selected, has been good.

## A CRITERION FOR SUBCONTRACTING

Although the advantages and disadvantages of subcontracting are clear, they are difficult to quantify. Frequently, the best decisions are those which are made on the basis of convictions, or hunches, or verbal rationalizations. Yet, since decisions are usually shared or need to be explained to others, those which are based on the simple criterion of dollar savings frequently are those which are selected.

An example of such reasoning, much simplified, is given below. It compares the cost of doing the work by the shipyard organization with the cost of a subcontract. In practice, cost estimates by a yard for its own performance may be optimistically low in order to avoid subcontracting.

The example uses a work package which by yard estimate requires $400,000 in material, $200,000 in direct labor, and $200,000 in overhead.

| | | Not Subcontracted | Subcontracted |
|---|---|---|---|
| Material | | $400,000 | 0 |
| Labor, direct, including engineering | | 200,000 | 0 |
| Overhead, percent of direct labor | | | |
| Fringes on direct labor, | 30% | 60,000 | 0 |
| Indirect labor, including fringes | 30% | 60,000 | |
| Depreciation, 7% | | 14,000 | $14,000 |
| Other fixed costs, 33% | | 66,000 | 66,000 |
| | Total | $800,000 | $80,000 |
| Subcontract | | | |
| Contract value | | | $680,000 |
| Services, to subcontractor, say | | | 40,000 |
| | | Total | $800,000 |

In the foregoing, if no dollar value is placed on the advantages of subcontracting, and if indirect labor and other fixed costs are considered unchanged by subcontracting, and if in addition the subcontract is charged some amount for services such as power, cleaning, etc. then the break even price for the subcontract is $680,000 or 15 percent less than the cost to the yard.

In practice each yard will decide for itself the individual charges for each alternate. Because such allocations are rarely known with confidence and the desired answer may influence them, the responsibility for initiating and deciding all "make or buy" alternates should be with the individual responsible for the profitability for the yard.

## PRODUCT WORK BREAKDOWN CONSTRUCTION AND SUBCONTRACTING

### PWBS AND ZONE OUTFITTING

Popular current terms which apply to ship construction are Product Work Breakdown Structure, Hull Block Construction, and Zone Outfitting. The objective is an increase in productivity,' to be achieved by doing *as* much work as possible on individual ship sections which are assembled in rapid sequence to form a complete ship. The concept and practice are not new. What is new is the systematic planning and determination to produce the ship in individual zones and larger sections each of which are individually substantially complete before they are joined.

These methods will improve yard productivity. Will they do so to the degree that subcontracting will not be needed? I think that the following observations are valid:

a. The Old-new methods will increase productivity within present yard organizations.

b. It appears each yard will continue to do most of the work with its force and within its shops.

C. It is too early to conclude whether or not these methods will make the yard departments specialists to the degree that outside subcontractors can become specialists in this method of construction.

d. Because the methods are predicated upon the ships to be assembled from building blocks, the opportunities for subcontracting may be increased rather than diminished. It is conceivable that a yard may buy all of its subassemblies and zoned units from others and finish and assemble them with a minimum work force of assembly specialists.

As pointed out earlier, production rates for steel vary among shipyards. Purchase of steel units by one yard from another, involving long distance barge transportation has been common. Such practice, generated by necessity rather than from deliberate policies of subcontracting, may well be viewed from the latter point of view by a yard committed to the new methods. Some yards can construct steel in the range of 40 to 60 man hours per ton but river barge yards appear to produce at rates

substantially less. With modular design of units it will be possible to take advantage of the assembly line production facilities of river barge yards and use the rivers as conveyor belts to bring completed units to final assembly points.

The zone system of outfitting appears consistent with the use of subcontractors who work either within or outside the yard. Of the three zone outfitting options, on-unit, on-block, and on-board, only the on-block unit requires a hull steel section as a working platform. Subcontracting would emphasize on-unit installations which naturally precede on-block installations. On-unit assemblies are being provided now without being so formally labeled. That each unit encompasses pipefitting, electrical work, painting, and other skills is not a disadvantage because such work is not assigned to separate crafts in the subcontractor's plant. Installation of these units by the same or other subcontractors on the zone blocks or on board ship would be the same as using vendors' supervision of yard personnel for the same purpose, a very common practice now. An obvious advantage of on-unit assemblies is that a few contractors can and do serve relatively many yards. Recall that complete deck houses are being built off the hull and lifted into place when completed. If that can be done within one yard then such deck houses can be built outside the yard by a single subcontractor to several shipyards. A similar practice for ship zones below the main deck, with completed zones being provided to shipyards should be equally feasible.

## CONCLUSIONS

The extensive subcontracting which I advocate is a major departure from the current practice of most shipyards, particularly at this time when many are already changing their manufacturing procedures. Yet, the concept has much merit. Consider that much of the work now subcontracted was once done by each yard. Clearly there were advantages to having others do the work. Additional subcontracting need not be done abruptly; most changes are better when they are gradual. But the increase in productivity will be determined by the pace of the change, if I am correct in my thesis.

The discussion presented does not exhaust the subject. Others should contribute so that the benefits of specialization as applied to the shipbuilding industry may be thoroughly explored. A particularly intriguing subject for discussion would be to plan a new shipyard based wholly on subcontracted zones. The new yard would be solely an assembly plant, perhaps the first true assembly line for manufacture of ships.

# THE UTILITY OF QUALITY CIRCLES AND PRODUCTIVITY TEAMS IN U.S. SHIPBUILDING

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## ABSTRACT

Quality circles have been found to improve productivity an average of 12% in 3 to 6 months in a controlled research pilot study performed by Business Innovations, Inc. for the U.S. Department of the Navy. Human relations and job satisfaction were also found to improve within a few months of starting quality circles at four companies. Quality circles (QC's) have been adopted widely by U.S. and Japanese industry and are increasingly finding acceptance in U.S. industry, including shipbuilding. The average return on investment for quality circles is 6 to 1. QC's are a simple, but effective, technique for problem solving which involves employees and increases motivation, communication, and productivity. They are a phenomenon of group dynamics not quality control techniques.

Implementation of quality circles needs to be carefully planned and should involve all levels of management and employees. An alternative to quality circles at foreman and management levels is "productivity teams". These involve more sophisticated training and the use of industrial engineering techniques. Productivity Panels and quality circles area low cost, high return investment for shipyards to cut costs and turn around companies with lagging sales due to decreased international competitiveness.

## INTRODUCTION

I would like to begin by asking how many of you are responsible for growth in productivity in your company? I think that includes all of us. Today I would like to discuss a way for you to receive the help and involvement of every employee in your company in contributing to productivity growth. That way is a new organizational activity called quality circles.

Quality circles, have been successful in organizing and motivating the human resources of companies to improve productivity and quality control in many industries, including shipbuilding in Japan, and more recently the U.S. Business Innovations recently performed a pilot study for the Department of the Navy on QC's from four U.S. companies including shipbuilding, electronics assembly, construction materials, and textiles. Initial conclusions showed that quality circles improved productivity an average of 12% within three months. The return on investment (ROI) of the circles in shipbuilding was 600%. Quality circles were also found to improve communications, cooperation, and job satisfaction, and to increase perceived importance of tasks and personal influence of employees as measured by pre- and post-test surveys.

Data from the study indicated success of circles depends on changes in organizational behaviour and employee perceptions which reduce barriers to communication and collaborative purposeful activity. Strong management support, professional training, talented program coordinators (facilitators), and open communications between circles and other departments are needed to effect these changes. Success does not depend on work situations, type of manufacturing, or characteristics of workers. Both union and non-union workers, as well as white collar, blue collar and management circles were equally effective.

Another finding of the Business Innovations study was that a quality circles type of structure of organizational relationships is needed at the management level. These are often called productivity teams because their scope is considerably broader than that of quality control. Productivity teams involve foremen, superintendents, department heads and upper management, instead of just employees. They use more sophisticated problem solving tools, including industrial engineering techniques. Productivity teams complement quality circles by creating effective problem solving groups at the management level which can interface with quality circles to create company-wide improvements in lateral and verticle communications, collaboration, and optimization of interdepartmental effectiveness.

## WHY WE NEED QUALITY CIRCLES IN SHIPBUILDING

The objectives of quality circles and productivity teams are ultimately to minimize cost and lead time of shipbuilding, repair and manufactured fabrications in shipyards. Presently, productivity is low due to problems arising from low worker motivation, material shortages, slow response from service departments, outdated tooling, parts below specification, scheduling and engineering problems, etc. These problems manifest at the waterfront job site and are experienced directly by workers and production management. They are therefore identifiable by foremen and their work crews.

However, many of these problems are often not recognized by upper or middle management prior to the slow down or work stoppage. The people in the work force know what is interfering with task completion, but this is often not presented to management in a usable way. Furthermore, the priorities of departments which should solve these problems are often directed toward projects dictated by upper management. Thus, lateral cooperation with work crews of other departments to maximize productivity and optimize total company output is lacking. No communication channels currently exist for these problems to receive the prompt attention of those persons in middle management whose involvement is necessary to help solve them and raise productivity.

Furthermore, foremen generally lack training in ways to improve productivity through the use of industrial engineering techniques, human motivation and group dynamics, quality control and problem solving skills. The foremen are key people who are in a position to improve productivity, yet they are not given the training or concepts of how to analyze and communicate their needs to superiors or subordinates. The consequences are poor productivity, high stand-by time, delays, cost overruns, reduced quality of finished product, low worker morale and decreased competitiveness of U.S. shipyards in the face of mounting international competition. It was concluded in SNAME SP8 report, Task EE-2 of 1/17/82 that increased training in productivity improvement techniques for foremen and supervisors, and better communication channels between management, industrial engineering, and labor are the most needed management techniques at the members' shipyards.

Many of the types of problems faced by foremen, superintendents, and department heads can be solved by quality circles or productivity teams. Furthermore, many of our current problems with employee motivation occur due to the failure to use principles of human behaviour which quality circles employ. Quality circles are especially applicable to shipbuilding because so much of the work is worker-paced rather than machine-paced and because interdepartmental coordination is so important. Furthermore, quality is

difficult to inspect in shipbuilding and expensive to correct if the job is not performed properly the first time. Quality circles and productivity teams directly address these well-known problems.

## DESCRIPTION OF QUALITY CIRCLES

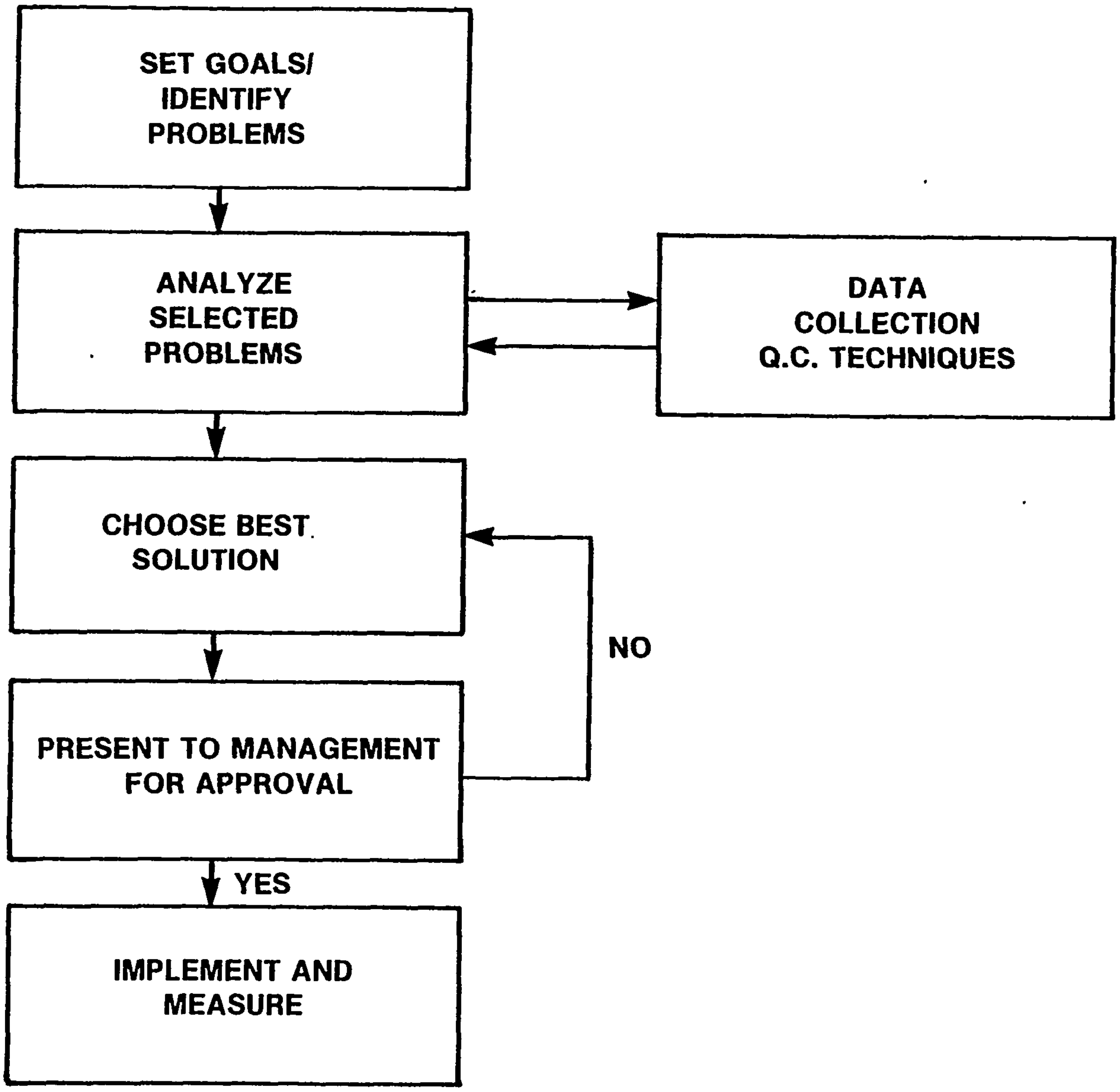
Quality circles are a technique of participative problem solving. They usually include 5-15 employees from the same department who meet for an hour a week with their foreman or superior to identify, analyze and solve problems which improve productivity, quality, or organizational effectiveness. Members may be employees, trades people, draftsmen, purchasers, secretaries, engineers or managers. Each circle has a leader who is usually the person in the chain of command to whom the circle members all report. The key element of quality circles is their emphasis on consensus decision making and the expertise of the person closest to the problem, usually an employee.

The activity of quality circles begins with the voluntary agreement of the members to participate. The group then sets overall goals which are related to objectives of the company. Improvement of productivity, quality, safety, or quality of work life are typical goals. Next the group identifies problems which, if eliminated, would help achieve the goals. The circle members choose by consensus which problems to work on. In so doing they take responsibility for the achievements of the group. This increases commitment of the group members to achieve the stated goals. The selected problems are then analyzed using techniques developed or adopted by quality control experts. These include check sheets, control charts, cause and effect analysis, pareto analysis, stratification, histograms, and scattergrams. They are all relatively simple applications of statistical analysis of quality control data. They introduce the element of the scientific method to the group's problem solving activities.

These analyses create a focus for generating solutions *to* the problems. For instance, the average waiting time for tools at one yard was found to be 12 minutes. The time loss was obviously great enough to warrant creation of additional distribution windows. In another case, on using Pareto analysis, 80% of the rejects were traced to two malfunctioning machines. Page seven is an illustration of a Pareto analysis of tubes out of tolerance.

Once the cause of the problem has been identified possible solutions are generated by group brainstorming. These creativity stimulating sessions often produce innovations which could even appear in technology transfer

## HOW QUALITY CIRCLES WORKS



programs or conferences such as this. Thus, quality circles are an innovation in human engineering which sets all minds in the corporation to continuously creating new productivity or quality improving innovations.

Once the best solution has been agreed upon, the entire quality circle makes a well rehearsed presentation to management. This is a valuable vehicle for employees to communicate their needs to management. Thus, another principle of quality circles is that decisions are made at the lowest level possible and are communicated upwards in the chain of command for approval. This creates two-way communication up and down in the organizational structure. QC's receive approval from management to implement their recommendations 80% of the time. The implementation is performed by the quality circle itself whenever possible, but the job is not complete until measurements are taken to demonstrate to what extent the problems have been solved.

## QUALITY CIRCLES IN SHIPYARDS

Quality circles were first adopted in the United States by Honeywell and Lockheed about 1974. Their success there and in Japan has led to their wide-scale adoption by about 2500 U.S. companies in the past three years, including well-known Fortune 500 companies. Among shipyards, the Norfolk Naval Shipyard was the first to adopt quality circles in 1979 and today has the largest program with about 60 circles. Since then, several other naval shipyards and three major commercial yards have experimented with quality circles.

The largest program in the private sector was started in 1980 at Lockheed Shipbuilding and Construction Company and currently has 36 circles. Several other shipyards have pilot quality circles programs or are planning to implement quality circles. Most of the major Japanese yards also have quality circles or their equivalent and have reported significant savings in costs as well as improvements in worker morale. One Japanese yard, IHH, has integrated quality circles style of functioning into the management system so completely that quality circles are no longer a separate activity.

Three of the U.S. shipyards have calculated return on investment of their quality circles programs. To do this the costs of training and meeting time plus costs of quality circle projects were subtracted from actual or projected savings from improvements made by quality circles. The following table shows the results to date:

| Yard | Date Started | # Circles | ROI |
|---|---|---|---|
| Norfolk Naval Shipyard | 1979 | 60 | 325% |
| Lockheed | 1980 | 36 | 400% in 1981 |
| | | | 1000% in 1982* |
| Newport News Shipyard | 1982 | 8 | 600%* |
| Bethlehem Steel (Sparrows Point) | 1982 | 3 | NA |
| Peterson Builders | 1981 | 9 | NA |

*Projected Savings

These results are similar to the U.S. national average of benefits to costs ratio for quality circles in all industries which is 6 to 1. In addition to these calculated cost savings many circles improve productivity, product quality, and other aspects of work flow which save money and increase profitability but are not normally documented. In Business Innovations' study for instance, one company improved productivity 13.4% in quality circles compared to control groups. This occurred in just three months time, long before any calculated cost savings due to specific quality circles implemented projects could be calculated.

Two circles in timekeeping at the shipyard in the study reduced rejects 14% in six months. Two circles in a purchasing department at the shipyard increased productivity 23% versus a 20% increase in control groups in three months while still planning, but not yet implementing any cost savings programs. These results show that quality circles increase motivation, since no procedural changes had yet been implemented. In addition to cost savings, quality circles were almost universally found to improve morale, job satisfaction, and communications with management.

Some examples of cost savings projects of quality circles in our study were:

1. Elimination of redundant approval checks on low-cost purchases. Savings: $500,000/year.

2. Reduction of inaccurate time cards through consultation with foremen. Savings: $55,000/year.

3. Elimination of a production step by designing a reusable chamfer for concrete slabs.

Norfolk Naval Shipyard gives the following examples of quality circles achievements:

1. Increased number of outlets in the tool room to reduce waiting time. Savings: $200,000/year.

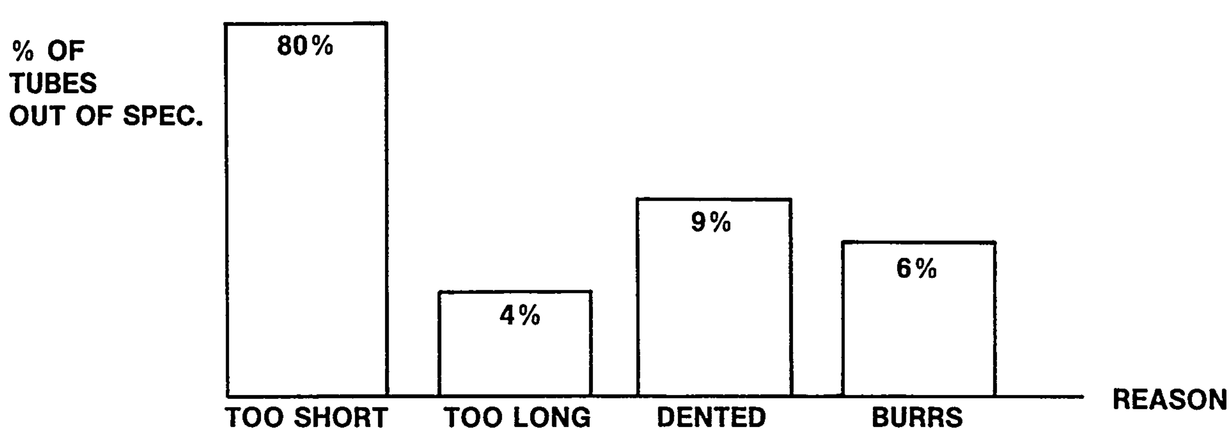
2. Movement of electrical stations. Savings: $10,700/year.

Lockheed Shipbuilding and Construction offers these examples of quality circles projects.

1. Re-examintion of sandblast material. Improved surfaces and saved $68,000/year in wasted material.

2. The welding circle developed a process to use weldable zinc primer. Savings of several thousand manhours/year.

## PARETO ANALYSIS



## METHOD OF IMPLEMENTATION

Although the format of quality circle activity described earlier has been universally adopted, the method of implementation varies according to the work situation and is important in how successful quality circles ultimately become at raising productivity. The first step in implementation is for the company to learn as much as possible about quality circles. Quality circles involve changes in bahaviour, attitudes, values and sometimes organizational culture which should be fully understood before they are implemented. A steering committee made up of representatives from every level of management and employees, including union stewards if employees are unionized, should be created to plan the implementation of quality circles and to set guidelines. Representation by all levels helps the committee foresee problems and improves commitment to the program at all levels of the organization. Since every level of management and employees will be affected by quality circles, it will be necessary to plan a program to increase awareness of what quality circles are and how they can benefit the company. This publicity will also be instrumental in ensuring that quality circles are well received and seen as an opportunity rather than a threat.

At this point a company may wish to involve a consultant who is expertly trained in behavioural sciences and quality circles. The consultant can help the steering committee in the above tasks as well as in selecting the facilitator, training the circle leaders and trouble shooting any problems that may occur during the start-up phase. The selection of the in-house facilitator or program coordinator is also critical because the circles are often dependent on him initially, and he is their chief liason with management. While most facilitators are successful, those trained in behavioural sciences were found in our pilot study to have generated the most outstanding examples of successful quality circles programs.

For several reasons a pilot program of less than ten circles usually precedes full scale implementation. This allows all concerned to become familiar with quality circles slowly. The most important implementation step is training. The circle leaders and facilitators receive about three to five days of training in problem solving, group dynamics, and quality control analysis techniques which they then impart to their circle members as needed. The training includes all of the knowledge and materials quality circles need to perform each step in the problem solving process.

## FACTORS AFFECTING SUCCESS OF QC'S

While the majority of quality circles implemented are successful, many circles and some entire company circles efforts do not succeed. The reasons for failures vary, but the most often cited problem is lack of support from all levels of management. Because quality circles involve changes in basic assumptions about how managers should interact with subordinates, many people feel threatened by quality circles and/or do not believe they will work. The best solution to this problem is to involve management in quality circles directly or in other organizational change programs which utilize principles of participative teamwork. The Lockheed Shipbuilding quality circles, for instance, are just one of several organization renewal programs at that company which together work to improve the use of principles of communication, collaboration and motivation in organizational behaviour.

Quality circles which involve department heads, superintendents, and engineers have been very successful at Peterson Shipbuilders, Lockheed Shipbuilding, Norfolk Naval Shipyard, and at other companies in Business Innovations' study. Also, circles in non-managerial white collar professional areas are particularly common in shipyards. These are found in engineering, planning and control, scheduling, drafting, timekeeping, data processing, etc. Not only were the management and white collar level circles able to take on problems of much greater scope than employee level circles, but because of their own experience, the managers who were quality circle members became highly supportive of other circles lower down in their departments. This usually occurs because people who become involved in quality circles or similar participative group activity experience an unusual increase in energy, creativity, cooperation, and progressive change. This is not a normal occurance in U.S. organizations which today encourage isolated, competitive individual activity rather than cooperative group dynamics.

Managers, who may originally be skeptical, quickly see that quality circles do not cause a loss of control due to their participative nature; they actually strengthen the chain of command by improving communications and mutual respect. If line managers in the departments where quality circles are created cannot participate in a circle of their own, they should at least receive training to familiarize themselves with quality circles methods so that they can assist circles in their departments when they need help. The importance of the involvement of management cannot be over-emphasized.

It should be clear that quality circles succeed because of the group dynamics they generate, not the use of quality

control techniques. Thus, this phenomenon which produces improved productivity and human relations at once is applicable to all levels of the organization. It should also be possible to create similar types of groups or teams at higher levels of management using more sophisticated industrial engineering (IE) techniques of analysis such as methods improvement, value and functional analysis, work simplification and short interval scheduling as needed. Lockheed Shipbuilding has attempted to accomplish this by having an industrial engineer meet with each quality circle as a resource person. The use of these IE techniques would be even more logical at management levels including foremen, since the problems they address and their analytic abilities are of a broader scope than employee-level quality circles.

Productivity teams at the foreman level and above could be as widely implemented as QC’s at the employee level. It would seem that an even greater ROI could be obtained from productivity teams than QC's, since management controls about 85% of the factors influencing productivity, and employees control only 15%. The involvement of management in productivity teams would, according to our research, create the support needed to make the principles of human organizational behaviour at work in quality circle types of activities successful at all levels of the organization. By taking this approach, Lockheed Shipbuiilding was able to increase its return on investment in QC's from 400% in 1981 to 1000% in 1982.

The second most important factor affecting success of quality circles is training. In our research we have found that training in group dynamics and the steps of problem solving are more important than the use of any quality control techniques of analysis. Some consultants mainly emphasize these quality control techniques, but several of the most successful programs, including Honeywell and Lockheed Shipbuilding, use very few of these techniques.

Like management involvement, union involvement is also a factor to be considered. Because quality circles give employees an opportunity to improve their jobs, employees are usually receptive. Most unions will cooperate or at least remain neutral about quality circles if consulted early on, since quality circles are so popular with employees.

An on-going tool to maximize results from quality circles programs is recognition of their achievements. Newsletters, awards, luncheons, and cash reward participation (as in suggestion systems) are all used widely to give recognition to the most successful quality circles.

A fifth aspect of quality circles functioning which is important to promote is the cross collaboration between

circles in different departments. Lockheed Shipbuilding more than doubled ROI from circles in 1982 partly because a sufficiently large number of circles operating in different departments were able to communicate directly with each other, whereas individuals would have had to go through multiple levels of hierarchy to achieve the same objectives.

## CONCLUSIONS
## REASONS FOR QUALITY CIRCLES AND PRODUCTIVITY TEAMS

1. Quality circles cut costs, increase productivity, quality and improve employee-management relations. They produce results quickly, within a few months.

2. QC's and productivity teams are a low cost investment, under $30,000, and they have a faster, higher return on investment than most automation projects.

3. QC's are especially applicable to shipbuilding because shipbuilding is worker paced and quality is difficult to control.

4. QC's and productivity teams create an atmosphere of communication, motivation, and involvement. They maximize the use of companies' human resources. This is the basis of productivity improvement, innovation and future competitiveness in international markets.

5. Productivity teams and quality circles are needed for future international competitivenes..

# SHIPBUILDING APPLICATIONS FOR THE ENGINEERING MODEL

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Mr. Baumgardner has extensive experience in the management of Engineering Design Modeling projects for the energy, aerospace, manufacturing and shipbuilding industries. He has directed numerous consulting and engineering design model programs for companies such as National Steel and Shipbuilding Company (NASSCO), Hughes Aircraft, TRW, Bechtel Power Corporation, Washington Public Power Supply, and Pacific Gas and Electric Company.

At Bechtel Power Corporation, Mr. Baumgardner worked as a Principle Engineering Model Deisgner for various nuclear power plant projects. While with McDonnell Douglas Corporation, Mr. Baumgardner served in both the manufacturing and manufacturing/engineering departments. In Japan, he was the Tooling Technical Assistant on a joint United States/Japan project. He was also Senior Project Tooling Engineer on various defense programs. As Manufacturing Program Manager, Mr. Baumgardner was responsible for a program with a $24 million manufacturing budget.

Mr. Baumgardner holds a MBA degree from the University of Illinois and a BS degree in mechanical engineering from the University of Illinois.

## ABSTRACT

This paper is based mainly on the Model Builder's experience at the National Steel and Shipbuilding San Diego Yard while working on the Navy's T-ARC7 program. It will present varied uses for Engineering Models in the Shipbuilding Industry and will discuss improved planning and design, lower design and construction cost advantages and improved problem-solving techniques.

I would like to thank the IREAPS Technical Symposium for inviting me to present this paper. I hope it will be educational and will stimulate discussion.

For many people, mention of the word "MODEL" brings to mind model airplanes and railroads - those relatively inexpensive, mass produced replicas of the real thing. Such models are mainly for personal pleasure and are thought of as toys and playthings. If someone with this background sees the price tag of a hand fabricated, sophisticated engineering design model, his reaction is likely to be, "WHAT AN OUTRAGEOUSLY EXPENSIVE TOY!" If, in addition, this person has had some previous connection with a poorly planned, improperly staffed and badly run model program.... Well, the resulting attitudes are very predictable!

Now, suppose a ship machinery space engineering design model costs $400,000. (Did I hear a few gasps?) And suppose the hard cash savings is $600,000. In addition, let's suppose the customer is willing to pay for the cost of the model . . . . . ..Sound interesting? If it is a multiple ship contract, it's looking even better! When evaluating a decision to use engineering models, we must look at the <u>VALUE</u> of the model, not just its cost.

For the past year and a half, Design Models, Incorporated (DMI) of Los Angeles has been building a 1½' = l'-0" (1/8th actual size) scale engine room model of a Navy cable laying and repair ship at the National Steel and Shipbuilding (NASSCO) San Diego Shipyard. The USNS Zues, designated T-ARC7, has the following principal characteristics. Overall length is 513'-6", with a beam of 73'-O", depth of 53'-0", design draft of 23'-10", displacement of 14,225 Tons and a power rating of 10,000 HP. Cruising speed is 15 Knots, with a cruising radius of 10,000 miles. The T-ARC7 is a diesel-electric ship. Five 2,500 Kw diesel generator sets power two 5,000 HP DC electric propulsion motors with direct drive, fixed-pitch propellers. The four 1,200 HP DC electric thrusters are tunnel type , two at the bow and two at the stern.

The model was set up as a design aid. It was initiated because of contract requirements by the United States Navy. However, since the model's inception, it has succeeded in winning wide acceptance by all levels of NASSCO personnel, and its role has greatly expanded.

NASSCO's in-house computer program for lines fairing was used to drive a drafting machine, tracing the frame shapes onto plywood. These sheets were cut out and used as templates for routing the frames from sheets of acrylic. Basic structure, model tables and equipment were fabricated at DMI's Los Angeles shop, then trucked to San Diego. Once there, the decks and equipment were assembled, and installation of piping, ventilation and cableways began.

In NASSCO's engineering building, space is at a premium. Therefore the original plan was to put the model in a building far removed from the design activity. Design Models fought hard to avoid this "KISS OF DEATH" for the model and finally convinced NASSCO management of the importance of placing the model on the machinery piping design floor. To accomplish this, the Commercial Ship Machinery Piping group and Mechanical group were moved into temporary trailers adjacent to the engineering building. The importance of location cannot be over-emphasized! Benefits derived from the model are somewhat like magnetism. Model usage is inversely proportional to the square of the distance between the model and the using agency. Double the distance, and derived benefits will be cut by a factor of four. For maximum benefit, the model must be at the point of usage - on the design floor during design and in the yard during construction.

Ten model bases, approximately 3 ft. by 4½% ft. by 7 ft. high, represented the machinery space. Two machinery rooms occupy the after one-quarter of the ship from keel to third deck. The ship was sized small for mission requirements, resulting in a very cramped machinery space. Ralph Bradford, NASSCO Chief Marine Engineer, compares the density in places to that found on nuclear submarines. The main design problem was one of trying to squeeze ten pounds into *a* five pounds sack!

The model served as a 3-dimensional composite, thus eliminating the need for costly composite drawings and their maintenance. The loss of composites caused initial misgivings among some NASSCO pernonnel; however, the tremendous aid to visualization gained through use of the model proved to far outweigh this loss.

As the model progressed, designers and yard personnel used the model more. They studied possible routings on the model. An occasional "Oh <u>*%#!!</u>" followed by a retreat to the board and the whir of an electric eraser were encouraging signs of the model's effective use. As NASSCO gained confidence in the model, DMI was allowed more freedom to do design work directly on the model. More drawings were made after the fact or were changed to correspond with routings developed on the model.

Now let's look at a few of the problems solved by this model.

Inner Bottom Saltwater Piping Redesign on the model, by DMI designers, reduced the 4" and 6" CuNi fitting by 25%.

Fuel Oil Transfer Line Redesign reduced the number of fittings on five, 4" steel lines from 40 to 10 and the number of direction changes from 75 to 45.

Main Propulsion Motor Foundation and Substructure Redesign increased strength and simplified design for improved produceability. Structural drawings were revised to dimensions developed on the model.

Electrical Cableway Redesign was required because of many interference problems found on the model. This is a diesel/electric ship, and the cableway density is very high. About 60% of all routings were changed. Isolation problems were also worked out on the model.

Fire Hose Lengthening resulted from running string from the various fire stations. 50 ft. lengths were found to be too short, so the hose length was increased to 75 ft.

Propulsion Switchboard Relocation was needed because of access door swing interference with stanchions. This would have been a very costly relocation if done on board ship after scribing, cutting and welding the switchboard to the deck!

Propulsion, Switchboard Overhead Clearance was increased after the problem was highlighted on the model. (The original clearance was only about 1".) Steel sizes were adjusted, giving a 3" minimum clearance.

7'-9" Level Grating Redesign on the model allowed installation per the engineering prints rather than costly development on board ship as was customary.

At this point, I think it is worthwhile to note that the problems mentioned so far were all created early in the program. In most cases, they resulted from designs made "independent" of the model. Later in the program, this type of problem was greatly reduced as designers learned to use the model in developing their designs, not just as an after-the-fact design checking device.

The model was used very successfully in the following areas:

Lighting Locations were developed on the model.

Access Forward of Machinery Room #2 Diesels was maximised using the model. Concerned Navy personnel were delighted with the final design.

Sloping Plumbing Lines Below the 3rd Deck were routed on the model. The galley is located above the switchboards, and gravity feed lines from the deck drain pots had very little room to maneuver as they sloped outboard to diverter stations.

Pre-outfitting the Underside of the 3rd Deck was smoothly accomplished with aid from the model. Pre-outfitting was unplanned until model designers pointed out the need based on cramped conditions above the switchboards and Enclosed Operating Space. Planning and sequencing for this operation were done using the model. It also proved invaluable in quickly solving problems encountered during the compressed-schedule pre-outfitting task.

I would love to talk about the many ways that models can benefit Engineering, Production, Planning and Scheduling, the Customer and Management, but time does not permit. I will include a summary of these benefits in the printed copy of this paper which will be sent to each of you after the symposium. At this point I think it is more important to look at the bottom line - COST SAVINGS, to look briefly at what the future may hold, and to leave a few minutes for questions and answers.

What were the cost savings derived from the T-ARC7 model? The total savings and impact will never be fully known. The only way to tell would be to reset the clock and run the same program with the same people without the model. This much can be said, however. The T-ARC7 is one of the most difficult machinery spaces designed and built by NASSCO. The design and construction has been accomplished smoothly without composite drawings but with an engineering model. Construction has progressed virtually free of problems caused by engineering design errors. Problems were successfully solved on the model, not on board the ship.

On an average machinery space, using composite drawings, NASSCO would expect about 225 Engineering Change Notices (ECN'S) on its machinery piping drawings alone. To date, on T-ARC7, there have been TWO ECN's! Installation of non-field-run machinery space piping is approximately 90% complete on the ship. Allowing for the increased complexity, let's conservatively say that the model saved just 225 ECN's. (The savings will be much greater when considering all engineering disciplines.) If we assume that the average cost per ECN is $1,500, that translates into savings of more than one-third of a million dollars. Elimination of machinery room composites might yield a savings of $110,000. Thus, looking at the resulting improvements in the machinery piping area alone shows savings in the neighborhood of a half million dollars. I am hopeful that NASSCO will run a comprehensive model cost effictiveness study at the end of the T-ARC7 project. I'm sure the total savings will be much higher.

The NASSCO Cost Engineering Department did do a cost feasibility study for commercial machinery space models. This study considered only the savings of eliminating composite drawings and of switching to single line piping drawings. These savings alone, more than covered the cost of a machinery space engineering design model.

I might point out that from the previous discussion, we saw how design savings were small when compared to savings realized in the yard.

Now, what does the future hold? Well, it looks like computer aided drafting is here to stay and that it will be playing an ever increasing role in the shipbuilding industry. Also, spurred on by the success of Japanese shipbuilders, it appears that U.S. shipyards will be using more modular construction techniques. How does the model fit in?

NASSCO has made a heavy commitment to use of computer aided drafting. Some of the machinery piping drawings for the T-ARC7 were drafted on the computer, and the designers made good use of the model. NASSCO designers and supervision find that CAD and the model compliment each other. There seems to be no conflict or duplication of effort. Each has its place, and both contribute to producing a superior design at a reduced cost.

More modular construction is being used by NASSCO on each new ship, but as yet, they have not made a total commitment to this approach as has the Avondale Shipyard in New Orleans. I visited this yard to talk with Tom Doussan, Vice President and Chief Engineer, and his staff. I toured the yard and witnessed their use of models as aids in construction of the modular units. Wherever I went, models were sitting by the modules as they were being constructed. Avondale has not used the model as extensively as they might have in the design area, but they are convinced of the value of this 3-dimensional aid to visualization in the yard during construction.

In conclusion: If properly planned, staffed and run, Engineering Model Programs in the Shipbuilding Industry work! They

* AID VISUALIZATION
* IMPROVE COMMUNICATIONS
* FOCUS AND COORDINATE DESIGN ACTIVITY
* SIMPLIFY PROBLEM SOLUTION
* EXPEDITE DECISION MAKING
* SIMPLIFY AND IMPROVE DESIGN
* ELIMINATE INTERFERENCES
*

M O D E L S S A V E M O N E Y

## M O D E L   B E N E F I T S   F O R   E N G I N E E R I N G

- o **3-DIMENSIONAL VISUALIZATION**
- 0 NO NEED FOR COMPOSITE DRAWINGS
- 0 POSITIVE INTERFACE ELIMINATION
- 0 FEWER DRAWING CHANGES
- 0 REDUCED RESEARCH TIME
- 0 SIMPLIFIED EVALUATION OF ALTERNATIVE DESIGN PROPOSALS
- 0 ALLOWS USE OF PEOPLE WITH LOWER SKILLS AND EXPERIENCE
- 0 SIMPLIFIED DRAWING CHECK
- 0 EASY ACCOMODATION OF HUMAN FACTORS REQUIREMENTS
- 0 SIMPLIFIED ENGINEERING / YARD LIASON FUNCTION
- 0 IMPROVED DESIGNERS' SKILLS
- 0 SINGLE LINE PIPING DRAWINGS

## M O D E L   B E N E F I T S   F O R   P R O D U C T I O N

- o SOLVES INTERFERENCE ON MODEL, NOT ON BOARD SHIP
- o PREVIEW FINISHED CONFIGURATION THROUGHOUT CONSTRUCTION
- 0 ALLOWS PRODUCTION INPUT EARLY IN DESIGN PROCESS
- 0 AIDS ERECTION AND ASSEMBLY SEQUENCING
- 0 PERMITS MORE EFFICIENT PERSONNEL ALLOCATION AND SCHEDULING
- 0 ALLOWS BETTER USE OF LESSER TRAINED PERSONNEL
- O SHOWS PROGRESS STATUS AT A GLANCE
- 0 AIDS IN INTERPRETATION OF ENGINEERING DRAWINGS

## MODEL BENEFITS FOR PLANNING / SCHEDULING

- o BETTER VISUALIZATION OF OPTIMUM
  - ERECTION SEQUENCING
  - EQUIPMENT LANDING SCHEDULING
  - SYSTEM INSTALLATION SEQUENCING
- o BETTER IDENTIFICATION OF PRE- OUTFITTING REQUIREMENTS

## MODEL BENEFITS FOR CUSTOMER

- 0 BETTER DESIGN
- 0 MORE COST EFFECTIVE DESIGN AND CONSTRUCTlON PROCESS
- 0 IMPROVED COMMUNICATIONS
- 0 SIMPLIFIED DESIGN REVIEWS
- 0 IDEAL OPERATOR TRAIMNING AID

## MODEL BENEFITS FOR MANAGEMENT

- 0 CONTINUOUS 3-D DISPLAY OF DESIGN STATUS AND PROGRESS
- 0 QUICK AND EFFICIENT DESIGN REVIEWS
- 0 QUICK AND EFFICIENT PROBLEM SOLUTION
- 0 FOCAL POINT FOR FOR INTERDISCIPLINE COORDINATION
- 0 RAPID TRAINING OF NEW OR INEXPERIENCED PERSONNEL
- 0 SIMPLIFIED CUSTOMER COMMUNICATIONS
- 0 BETTER SCHEDULE COMPLIANCE
- 0 DESIGN CORRECTIONS ON MODEL, NOT ON BOARD SHIP
- 0 COST SAVINGS

# MOST COMPUTER SYSTEMS: INTER-SHIPYARD DATA TRANSFERABILITY

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Mr. Kuh holds a BSME degree from the University of Colorado, and had graduate study in industrial engineering at the University of Iowa.

## ABSTRACT

Over the past year and a half, five participating shipyards have been preparing labor time standards using MOST Computer Systems on a time sharing basis. The result has been the development of separate databases covering the following operating areas: blast and paint--platen and dock areas; Electrical--shop and outfitting; main assembly; fabrication shop; and staging erection and teardown--platen, dock and ways. The ability to transfer data from one yard to another is discussed, as well as the methodology for such transfer. The actual use of transferred data and its application is covered to the extent that it has occurred up to the date of the symposium.

## Introduction

One of the features. of the MarAd SF-8 Panel's FY81 project for Labor Standards, has been the use of a common Data Base **within** the time shared MOST Computer System. The practice is a cost effective method of introducing Computer MOST to the shipyard industrial engineering groups. At the same time, the future transfer of data had been considered to be possible, but not necesarily probable.

In fact, the Panel had intended to establish a system of Standard Data that would indeed be useable by the shipbuilding industry. At the present time, that step is. still in the future. However, there is a considerable degree of interest in the feasibility of data transfer in order to expand the coverage within a yard on a timely basis - and without greatly expanding the industrial engineering group.

BY early spring 1982, we had reached the conclusion that the transfer of data was feasible. A few tests conducted at the participating yards - particularly at Bethlehem Steel's Sparrows Point yard - taken in conjunction with the work done on data adaptation for Peterson Builder's Pilot Program for Pipe Shop Scheduling, and a Gross Estimating System for Newport News, provided the basis for the conclusion.

## Summary

The data that is available is sufficient to cover between 50% and 80% of shipbuilding operations. BY using the transfer approach, a yard can achieve full coverage of its shipbuilding operations in approximately one half of the time required to develop al 1 of the data from scratch.

Transferabi1ity is NOT applicable to completed Time Standards that apply to complete components of a ship. Even if two yards are building the same ship, there are enough differences in work methods and processes to make it more than doubtful that the same labor hours apply.

The transfer of sub-operation data is feasible -- and desirable in terms of time and cost.

Process Data MAY BE transferable. Process times developed for machinery and equipment is transferable for like machinery and equipment, as long as the process time is essentially machine controlled.

Welding process. times ARE transferrable, for similar' welding methods, equipment and electrodes - particularly when the data is taken from the Welding Module of Computer MOST.

In all cases, some additional data wi11 have to be developed, since there are differences in processes, and in the scope of work covered by specific crafts and trades.

Data transfer is considered to be more economical than completely new data development for at least two reasons. First, there are very few yards that have an established Work Measurement group within their Industrial Engineering Section. (If they DO have an Industrial Engineering Section.) Regardless of the background of the analyst selected, the transfer of data provides an invaluable training method either in the use of manual or Computer MOST, or in making the analyst knowledgeable about a given work area.

Second, there is a significant saving in the time required to develop data.

## Defining Transferability

“The quality or state of being transferable.” That is the Webster definition for transferability.

With respect to Work Measurement Data, there are two sub-definitions that must be added:

1. Transferabi1ity ‘as is’

2. Transferabi1ity - with modification.

Transferabi1ity ‘as is’, may be defined as the direct use of work measurement data elements at locations other than those where the data was developed. Data considered to be tranferable “as is”, wi11 be referred to as ‘transfer data’.

Transferability - with ‘modification, may be defined as the modification of work measurement data elements to accomodate different work place or work area layouts and arrangements found at other than the location where the data was developed, Further, modification may. be required for process time values. Data considered to be transferable with modification will be referred to as ‘modified data’.

## Accuracy and Precision

Before proceeding, it is important to establish the accuracy levels required for the application of work measurement data, and the precision required, in shipbuilding.

The shipbuilding industry (with a few exceptions) does not have a background of work measurement application as a management tool. Nevertheless, the industry has used and is using a version of

labor standards for bidding, planning, scheduling and manloading. The data used is most often based on historical information gathered on a return cost basis. Return cost being defined as the time values reported and collected through the existing accounting system and budget procedures.

Without discussing or attempting to evaluate the accuracy of the return cost data, let's consider the validity of 'historical'standards.

Historical time values have the disadvantage of including every mistake, error and delay that has occurred. Whether or not 'improvement factors.' are used to reduce the historical time, there is seldom a factual relationship between those improvement factors (e.g., historical average less 10%) and what may be the time that is genuinely required.

Given the fact that workers will attempt to acheive a work time target, budgets WILL be matched **3.5** long as they are not beyond the capacity of the worker as an individual or as a group. Only supervisory ability will lead a group to perform under budget - and the 'unusual occurance' (such as a crane breakdown) is a ready reason for 'over budget' events -- even though such delays are a part of the historical time used to establish the original budget .

The introduction of work measurement techniques to establish Labor Standards provides a degree of accuracy that has been previously unknown. But, it is not practical or realistic to anticipate that a shipyard will - or can - immediately convert from existing practice to a rigid management control system based on accurate labor standards. It IS practical and realistic to expect that a shipyard will prefer to use accurate data in conjunction with sound estimating and risk factors to improve and expand their management control tools.

All of which leads to the conclusion that labor data used should be accurate within the normal limits of work measurement (+/- 5%) but should not be required to match the precision expected of standards used in most manufacturing operations.

MOST systems include a recognition of the accuracy requirements for al 1 work measurement techniques -- and continues to provide a precision of five decimal places in the developed data. The experiences of the past year have demonstrated that in most cases, a precision of three, two, or even one decimal place is both practical and suitable for shipbuilding.

## Impact of Data Application

Considering the requirements of accuracy and precision, there are two application areas that may not be suitab1e for the use of data transferred from other shipyards. Those areas are:

1. Labor Incentive Systems, and

2. Labor Performance Reporting and Analysis coupled with supervisory accountability.

Those areas require the use of data that is both accurate and traceable to provide management with the back-up required to secure supervisory and worker cooperation. Data accuracy is also required to provide the background necessary to modify the standards as methods, processes and conditions change. Transfer Data will satisfy the requirements, but could require as much time and effort for validation as it would take to develop site specific data. Modified Data could require as much or more time to develop than would site specific data.

Wherever Work Sampling Studies are used to develop modifiers for the determination of 'application standards', and wherever judgement factors ( or risk factors) are applied, both Transfer and Modified Data are applicable.

## Data Review

Since the Standards program began in late 1979, a total of ten Work Management Manual (WMM) sets have been produced, six of them by manual methods, and four by computer. Those sets are:

A. Manually prepared:

1. Bath Iron Works, a) Hardings Plant C Bay; b) Hardings Plant B Bay; and c) Hyde South Assembly Building.

2. Bay Shipbuilding, a) 'All' -a general manual; and b) Graving Dock & Platen Area.

3. National Steel and Shipbilding, a) 'All' - a general manual; b) Panel Line; and c) Platen Area.

4. Newport News Shipbuilding and Dry Dock, Blast and Coat - Platen and Graving Dock.

5. Peterson Builders, Pipe Fabricating Shop.

6. Sun Ship, Blasting and Coating Facility.

B. Computer prepared:

7. Bath Iron Works, Main Assembly Building.

8. Bethlehem Steel, a) General, Temporary Staging for Ground Assembly and Aboard Ship; b) Wire Rope Handrai 1 for Ground Assembly; c) Pipe Staging for Aboard Ship, and d) Bracket Staging for Aboard Ship.

9. National Steel and Shipbuilding, a) General for NASSCO Plate Shop; b) Brackets; c) Foundations; and d) Ladders.

10. Peterson Builders, a) Electrical General - Electrical Work for Shipboard Installation; b) Shoot Studs on Bulkhead in Ship; c)_ Cut 25WU-7 Cable; d) Pack MCT Onboard Ship; e) Prepare Electrical Box for Installation Aboard Ship; f) Install Electrical Switch Aboard Ship; g) Terminations at Electrical Panels; h) Attach Plug to the End of Designated Cable; and i) Test Distribution Panel #500 VAC.

The appendix is an index of the data available, covering thirteen work areas, and five types of ships.

The overall quality of the material in terms of its transferability, ranges from Good to Excellent. The following general comments are in order.

The various Glossaries that are appended to many of the manuals do not provide definitions for some "local" terms. Whenever there are questions about the meaning of some terms, it is recommended that a call be made to the appropriate yard to get a definition of the terminology used. Unless such an approach is taken, useful data may be discarded through misunderstanding. Of course, if definitions are assumed, some data may end up being misused.

Most manuals provide sketches of the products involved that also serve as a definition of the operation covered, and of the terminology used.

The work area and workplace layouts provided in the computer prepared manuals may seem to include several duplicates. In fact, the duplication is of the arrangement, but not of the tools, or equipment or spatial relationships covered.

The material contained in the Newport News manual (Blast and Paint on Platen and in Dock<) has been prepared with Maxi-MOST, and requires an understanding of that technique before use.

Al though each data set was developed for a particular type of ship under construction, the bulk of the operations are

independent of ship type. Of course, there are those operations required for HY-80 steel that are exclusive to Navy construction, but those factors affect the coverage available, not the validity of the data.

## Personnel Requiremnts

As a general rule, it is more cost effective to select personnel who have knowledge of the work area and the capability to be trained in Industrial Engineering techniques, rather than trained analysts who have no knowledge of the work area to be covered. Frequently the best candidates may also be candidates for first line supervisory positions. A temporary appointment to the Industrial Engineering group should be considered as an excel lent training step for line promotion.

There are situations that may dictate how personnel are selected, and what the source will be. In most situations, training will be necessary. Whether the training must be in the work area involved, or in MOST, the transfer of data provides a superior 'on the job' training procedure.

When MOST analysts who are unfamiliar with the work area must be used, the transfer technique becomes a training aid, as well as a way of reducing data development time.

Reference to an existing WMM is an excellent method for introducing the analyst to the work methods and procedures of the area to be covered. By having hard copy of the sub-ops in hand when he goes to the shop, he has a guide to understanding what he sees. At the same time, he can readily evaluate how much of the data is usable, and where he must develop new data.

When adding someone familiar with the work, but who needs to be trained as an analyst, the transfer concept is a most useful training device. The basic 'classroom' training cannot cover all of the situations the analyst will encounter, and it seldom provides the kind of practical guidance for sub-operation structure that analysts can only glean from the guidance of an outside consultant, or from the experienced analysts in the yard, or from three to four months of trial application. The data transfer technique will provide important guidance in sub-op structure, and will accelerate the new analyst's learning curve.

## Transfer Procedure

The actual 'manipulation' of existing data is the primary difference in the use of transfer and 'modified data between those who use manual MOST and those who have the advantage of Computer MOST. A review of the procedures involved, provides an' excel lent evaluation of the advantage of transferring data over the development of new data.

1. New Data development:

   a. Visually analyze overall 1 operation and record:
      1) Work Area (sketch)
      2) Operations performed, manual and machine.
      3) Number of operators.
      4) Tools and equipment used.
      5) Distances between work places.

   b. In note form (while at workplace) write step by step procedure for doing the work.

   C. Transcribe notes and information to MOST forms.

   d. Write up the sub-operation? determining MOST sequence and segment valves.

   e. Calculate the sub-op time value.

Maynard experience indicates that the above procedure will require approximately 10 hours of analysis for each hour of work analyzed.

2. Transfer Data using Manual MOST:

   a. Using a hard copy of the existing sub-operation and its accompanying layout, visually or synthetically analyze the overall sub-op. Annotate hard copy to indicate the differences found, and to check the similarities. Check the arrangement and distances on the layout.

   b. If necessary, prepare a revised work place layout .*

   C. If necessary, rewrite the sub-op methods steps, and the appropriate MOST sequences and segment values.

   d. Calculate the revised sub-op time value, or accept the existing sub-op and its time value.

Depending on the ski 11 and knowledge of the analyst and the amount of revision required, between 4 and 8 hours of analyst time is required per hour of work analyzed.

3. Transfer Data using Computer MOST:

   a. Same as step 2a, above.

   b. If necessary, use the computer to edit the work place layout to the noted configuration and distances. *

   C. If necessary edit the methods steps in the computer. If the only change is the layout and associated distances, allow the computer to recalculate the sequences and time values.

d. Al low the computer to calculate the sub-op time value.

Depending on the ski 11 and knowledge of the analyst, and the extent of modifications required, between 2 and 5 hours of analyst time is required per hour of work analyzed.

* When the analyst determines that the distances are within the range of the MOST Index, changes are not required. See Figure 1.

In consideration of the vast amount of different work involved in the shipbuilding process, anything that promises to reduce analyst time without sacrificing accuracy should be a desirable action. In most Industrial Engineering Departments, available standard data is used whenever the accuracy and precision provided is within the requirements of the manufacturing operations.

## Data Transfer and Work Methods

With few exceptions, we do not train shipfitters (or other craftsmen in shipyards) in the better methods of work that may be available.

For example, we have found a variety of tools and methods used by electricians for stripping wire leads. Obviously, it is neither realistic nor practical to prepare data for each method encountered.

The accepted practice is to prepare a sub-op for the most feasible - and better - method encountered. Where significant time differences exist, it has been the practice to prepare a methods improvement, and to work with shop management to insure that all of the workers have been instructed in the better method.

Obviously, the use of data transfer could and should have the same impact on methods in use. When a sub-op is reviewed for transfer, and there is a different method, consideration should be given to picking up the new method IF a savings is indicated.

Those yards that have existing standards - whether used for incentives not, should make a different evaluation of transferability. The data that is in the manuals may be used to review existing standards for completeness and accuracy. Certainly when time study has been the basis for the existing standard, the accuracy and completeness of data back-up that is available within the Work Management Manuals may be the basis for a planned conversion - over an extended period - from one system to another.

FIGURE 1

MOST Distance Ranges

| MOST Index No. | Distance Range - in Steps From | Up to and Including |
|---|---|---|
| 3 | 1 | 2 |
| 6 | 3 | 4 |
| 10 | 5 | 7 |
| 16 | 8 | 10 |
| 24 | 11 | 15 |
| 32 | 16 | 20 |
| 42 | 21 | 26 |
| 54 | 27 | 33 |
| 67 | 34 | 40 |
| 81 | 41 | 49 |
| . | . | . |
| . | . | . |
| , | . | . |
| 330 | 175 | 191 |

## Conclusion

Over the past two years, MarAd has invested something over $1,250,000 in the development of Engineered Labor Standards for shipbuilding. The basic data developed during the programs is available to those shipbuilders who are interested.

Transferability is concerned with the ability of any yard to pickup and use data that has been developed. That ability exists. The sub-operation data is well developed, and can be used wherever the specific operation is used.

The coverage provided by the existing data varies from shipyard to shipyard, depending on what work is actually performed on the premises. For example, the Electrical Shop manuals provide coverage for the bulk of any electrical work. However, since the developing yard is small and purchases components and services to a greater extent than larger yards, there are additional operations at the larger yards that are not covered by the data. Also, cable sizes are relatively small, and the activity involved in pulling large and heavy cables is also not covered. Nevertheless, the existing data represents approximately 80% of the electrical work involved in shipbuilding.

The major activities NOT represented in the manuals are:

1. Warehousing
2. Material Handling
3. Sheet Metal fabrication and installation.
4. Pipe installation
5. Machine Shop
6. The installation of machinery, lighting, most outfitting operations, and
7. Indirect operations such as Maintenance and Custodial.

Data transferability is feasible, and will provide coverage at 50% to 80% of the cost required to develop new data.

Those yards that have not participated and that do not have the resources to warrant the establishment of an industrial engineering group may not be in a position to take advantage of the mass of data that is curently available.

Hopefully, there will be progress towards conversion of the data to a Standard Data format, and the provision of an application procedure that can be applied to almost any shipyard's operations, with a minimal technical staff requirement. Such a program is a logical extension of the SP-8 Panel's activity to develop and apply industrial engineering techniques within the shipbuilding industry.

# Index of Data

I Pipe Fabrication - PBI (Patrol Gun Boat)

Covers pipe sizes through 8" Diameter; Copper, Copper Nickel, Mild Steel, Galvanized, and Stainless Steel pipe.

A. Bend Pipe - Greenlee Benders - 2", 4", and 6"
-* Conrac Bender - tooling for 2" through 4".
-* Anneal Copper pipe for bending.

B. Cut Pipe - Marvel Bandsaw. Includes debur, bevel and grind.

C. *Clean pipe after Conrac bender,

D. Use portable Bevel Grinder.

E. *Thread pipe on threading machine.

F. *Drill pipe for O'lets.

G. Braze pipe - use sil-braze rings.

H. Fit and Tack ferrous pipe.

I. Weld pipe in vise and in positioner.

J. *Inspect assemblies, cap and tape openings.

K. *Bolt Flange Assembly.

* Supplementary material not in original WMM.

II. Electrical Shop - PBI. (Patrol Gun Boat)

A. Cut Cable to Length at Cable Shed.

Includes measure on floor, cut, mark, tag, coil, tape and load cable on pallet for delivery to ship or to storage.

B. Prepare Electrical Boxes for installation.

Includes drilling holes, punching holes (porta-punch), and other operations necessary to get boxes ready for installation on ship.

C. Assemble Plugs.

Includes preparing cable, conductors and leads, placing of plug hardware, identification tubing, shrink tubing, soldering connections, and final assembly of plug.

D. Shoot Studs with Weld Gun.

Includes al 1 setups and operations required to weld studs to bulkheads or equivalent.

E. Pull Cable, Pack MCT (Multi-cable transit) .

Includes preparing cables for pulling, pulling through hangers, banding and tying in place on hangers, and the complete assembly of the MCT.

F. Install Electrical Equipment.

Includes al 1 operations {punch, drill, fasten) to install electrical boxes on ship.

G. Terminate Cables.

Includes installation of stuffing tubes on boxes, al 1 preparation of cables, conductors and leads for service loop and individual routings and connections. Labelling of leads, installation of lugs, and connections in boxes. Also covers installation of electrical components in boxes.

H. Test Fixture.

Includes al 1 operations required for megger testing.

III Panel Line - NSS (NASSCO) (Tanker)

A. Fit and Tack - ESAB Crane and Press.

Includes inspect and code plates, align plates, prepare to fit and tack', fit and tack, and moue panel to weld area.

B. Weld Panel

Includes moving tacked panel in, completed panel out. Set up and tear down of ground clamps, track, and sub arc mathine. Move track and machine to next seam, service machine with flux and wire, panel turnover, welding and filler pass.

C. Grind. Covers grinding weld for pickup.

IV Fabrication and Assembly of Small Components. - NSS (Tanker)

A. Brackets

Includes necessary setup, teardown and transport for burning machine, shear, brake press and C press for forming docking brackets.

B. Foundations

Includes necessary setups, tear downs, transport and operation for sawing, shearing, bending, punching, drilling, fitting (in jig) tacking and welding components for a typical foundation.

C. Ladders

Includes operations (see Foundations) necessary to fabricate and assemble ladders with handrails in jigs.

v Assembly of Small Components (Steel and Aluminum) - BIW (Fast Frigate)

A. Layout

Includes, get parts and place, get instructions, measure and mark, and moue marked parts to storage with location notation in log.

B. Fit and Tack

Includes get instructions, parts and fitting aids. Check layout as needed, transfer layout opposite hand, fit various parts and shapes, grind to fit, burn to fit, tack weld, and mark assembly identification and weld requirement.

c. Weld

Includes al 1 necessary set ups, moues (manual and crane) and cleaning operations to final weld assemblies.

VI Assembly of ‘over-the-highway’ transportable Bulkheads and Webs. - BIW (Fast Frigate)

A. Fit and Tack.

Includes get instructions, manual and crane transport, layout, mark, scribe, makeup, install, tack, and grind parts, and mark assembly with identification and weld data.

B. Weld

Includes al 1 necessary operations for manual (stick) and semi-automatic welding of assemblies.

VII Assembly of Curved Shell Sections - BIW (Fast Frigate)

A. Fit and Tack

Use IT 'Come-along’, 6T Come-along, Porta-power jack, Dog and Wedge, Panel jack, and Bolt & Clip fitting aids. Land and fit plates to ‘Mock’(permanent pin Jig) fit and tack plate seams, install strongbacks, layout for grinding and framing, land fit and tack stringers, webs, collars, headers, tanks (and regulate) brackets, stringers, chocks, etc. Mark assembly for welding.

B. Weld

Setup, prepare to weld, change rod and reel and clean weld area for manual and semi-automatic welding.

VIII Install and Remove Staging - BSC (Sparrows Point) (Tanker)

A. Wire Rope Handrails.

Al 1 necessary operations to erect and tear down welded and bolt-on stanchions, including nuts welded to web or bulkhead for stanchion service. Run and remove wire rope handrail.

B. Pipe Staging.

Al 1 necessary operations to erect end panels and braces, lay planks, erect stanchions and pipe rails. Transport by crane to material supply and to erection location, transport by hand to point of erection. Includes climb up and down.

c. Bracket Staging

Weld and burn bracket clip, ladder clip, stanchion and handrail. Set up and remove ladders, climb up and down ladders, and transport materials and tools by grove crane, winch, tower crane, and aerial platform. Erect and remove brackets, stanchins, rails, and planks.

IX Assemble Erectable Units on Platen - NSS (Tanker)

A. Layout

Establish squaring lines, horn/measure diagonals, use Steel Tape template to set frame and long lines. Snap chalk lines, centerpunch, use paint stick and stencil. Pitch two plates.

B. Burn Plate for butt fit

Set up for manual and Bug-O burning.

C. Fit

Moue and align panels, plates, and parts with porta-power, chain hoist, pry bar, and dog and wedge. Weld and remove fitting aids such as dogs, saddles, strongbacks, andclips. Fit and tack all parts such as plates, bulkheads, webs, longs, collars, padeyes, collars, curved plates, transoms, frames, floors, etc. Set up pin jig and plate stops.

D. Weld

Supply, set up and tear down operations for sub-arc, straddle buggy, electroslag, gravity feed and arc gouge. Use needle gun, and weld lugs.

E. Chip and Grind

Set up, tear down, and operate pneumatic chipper (chisel) and disc grinder.

X Assemble Erectable Units in Assembly Building - BIW (Fast Frigate)

A. Shipfitting - Steel - Upper unit, Lower unit and Join,

1. s-et up.

Steel plate, CVK assembly and main deck assembly on permanent jigs.. Seams, stringers, web frames, bulkheads and second deck assembly. set and regulate tank-top assembly unit in upright position in jig, and upper unit onto lower unit.

2. Layout

Shell for framing

3. Make-up

Stringer, web frame, stiffener tie-butts and bulkheads to bottom shell assembly and to deck.

4. Install and/or Combine

Collars, brackets, chocks, headers, intercostal frames, seachest, manholes, rings, foundations, stanchions, tanks, reefer skirting, bulkheads on deck, side shell to unit and cross-flooding baffles and enclosures.

B. Shipfitting - Aluminum deck house and superstructure.

1. Set Up

Deck on permanent jig and bulkhead on deck.

2. Make-ready

Deck for scribe, bulkhead on unit, and fitter for job.

3. Make Up

Deck seam or butt, stiffener connections on deck, bulkhead to deck, vertical seams, house side to deck and on unit, and web frames to transverse girders.

4. Install and/or Combine

Collars, brackets, foundations and headers.

C. Welding,' Steel and Aluminum

Per Foot values for all welds, and Per Piece values for typical aluminum components.

XI Blast and Paint in Facility - Sun (Container Ship)

A. Prepare for Blasting

Erect 1 adder and back rail, install lighting and ventilation and place rolling staging. Wrap pipe, values, fixtures and pipe ends. Suit up.

B. Blast (steel grit)

Moue staging and climb to change location.

C. Clean up

Get equipment and return.

D. Prepare Unit to Paint

Get and return materials, tools and equipment, suit up, moue staging, and climb to change location. Mask Edges and stripe.

E. Paint

Moue staging and climb to change location.

F. Clean up Unit

Remove back rail, ladder, ventilation, lighting, masking and rolling staging.

0. Clean Up. Facility

Scrape floor with "Bobcat" and shovel leftover grit.

XII Blast and Paint on Platen, In Dock - NNS (Tanker)

A. Blast - Prepare Operator

Get and put on protective clothing, apply tape as required, put on hard hat and safety glasses.

B. Blast - Load Machine

Use fork1ift to get and return hopper. Climb to operate values on hopper and blast machine to fill machine.

C. Set Up Air Compressor

Check oil level, start compressor, adjust flow, check at blast machine, bleed moisture from air1ine and blst machine, open and close values as needed.

D. Set Up JLG (Cherry picker)

Carry and setup blast hood, blast hose and airhose at JLG basket . Turn JLG on, climb in basket , attach safety belt, moue basket to location, put on hood, grasp blast nozzle,

E. Set Up on Unit

Carry blast hood to area, climb to location, put on hood, grasp blast nozzle.

F. Set Up Vacuum

Go to vacuum unit with shovel, empty dust box, position and atach tubing. Align and tape 4 pieces vac hose to unit, pull hose up ladder into unit, position, and turn on Vacuum.

G. Moue Tools for Grit Removal

Carry shovel from store to unit, up 1 adder, and position. Attach air hose to 1ine, pull to unit and up 1 adder, and position to blow down dust.

H. Remove Tools and Equipment

Reverse operations to remove blast hose and vacuum hose from unit, coi1 and stack blast hose.

I. Paint - Prep Operator

Get coveralls, put on. Put on hard hat and safety glasses. Carry face shield and spray gun to work area, put on shield.

J. Set Up Paint Pump

All operations necessary to get paint pump, attach air and paint lines, mix and strain paint, start pump and paint flow.

K. Set up JLG for Painting

Pull paint line and air hose to basket, attach. Start JLG and climb in basket. Raise to working position, attach air hose , grasp spray gun.

## XIII Assemble 'Super Section' on Platen, Erect in Dock - Bay (1000 Foot Bulk Carrier)

A. Rigging

Hook and unhook various sections on transporter, platen, ground, stack, in turning area. Rehook and unhook to turn on side shell. Unhook in Jig or on hull. Various operations with cables, spreader bar and shackles.

B. Layout

Measure for scribing, setup scribe block, and scribe. Set-up and take down transit on tripod (hull and ground) and on portable rail stand. Use transit with pole and tape measure. Use Plumb bob and line. Measure with 50' steel tape. Mark with soapstone and center punch.

C. Burning

Set up, tear down and use Bug-o and hand torch.

D. Fit

Get tolls and equipment. Fit and fair with fairing clips, dog and wedge, angle butt jig, bolting dogs, bolting angle clip, and cab1e/turnbuckle. Get, use and return chain jack, bottle jack, power hoist. Use power hoist with safway and skyclimber.

E. Weld

Set up, take down, get supplies for, and use manual welding equipment.

F. Grind

Grind with portable air grinder.

# PRODUCTIVITY ISSUES IN NAVAL SHIPBUILDING

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ABSTRACT

Productivity is looked upon by most as the key to our American standard of life; however, as evident by the successes overseas, the United States seems to be only now coming to grips with the true essence of productivity -- human resource management. This paper will look at the changing nature of productivity as it relates to job design, participative management, and the increasing use of incentives, feedback, and goal setting. Likewise, a brief discussion of organizational design and recent developments toward work motivation will point up that the real key for productivity improvements lies with management. This then will help establish why there are real productivity issues that need to be addressed in the Navy shipbuilding program in the areas of engineering design, waterfront management, and Navy Project management. The essence of these issues relate hinderances to achieving productivity improvements due to: (1) poor organizational structures which preclude inclusion of productivity considerations early in the design phase; (2) improper attention and training provided to the first level supervisors at the waterfront and the failure to recognize the valuable contribution these people could provide; and, **(3)** the crucial requirement for having qualified and experienced ship production personnel on Navy management teams.

## I. INTRODUCTION

Has the necessity to meet tight schedules and constrained fiscal demands precluded the Navy and shipbuilder from realizing their role in improving productivity? On the contrary, we feel that just because of these demands, attention to shipbuilding productivity is even more crucial. Productivity issues in Navy shipbuilding can encompass many aspects, from management to industrial capabilities. We believe however that management, in broad terms, is the key factor, both in the production environment and design development as well.

The generic definition of production is the act of producing, but we all know that in Navy shipbuilding the real definition is based upon the successful completion of a system within cost and schedule, while realizing maximum efficiency. Navy shipbuilding, by its nature, is a complex and cumbersome effort, never totally suited to optimum productivity from technology alone. Therefore, the Navy shipbuilding community must look beyond the obvious plant capability issues and look at philosophies and methodologies in the way the community conducts business and manages its projects.

This paper intends to point out the need for the entire Navy shipbuilding community, including Navy management, to examine current philosophies, to get beyond the reactive response mode and begin to reassess management capability at every technical level. There is a need to reassert ourselves to recognize the uniqueness of Naval construction ***as a*** specialized industry to be managed by highly experienced and dedicated shipbuilding people, who will call upon their technical experience and the recent develpments in human resource management to create a positive impact on shipbuilding productivity.

Our intent here is not to attempt to provide the ultimate specification ***for*** management success, but with a great deal of objectivity, to make observations based on our experiences which directly and indirectly are affecting productivity today.

### The Nature of Productivity

***In*** the business and commerce world, management, labor and government all recognize that productivity has been the key to our American standard of living and that steps must be taken to enhance it. Despite this fact it is interesting to note that there is no universally accepted definition of just what productivity is. That is, there is no single set of measures or indicators which a business or government agency can utilize to measure its productivity. Different measures are used in different situations. However, it is generally accepted that productivity is thought of as a ratio concept -- the ratio of the output of goods and services produced and generated by an organization divided by the input used to produce them. ***In*** such a labor intensive environment as the shipbuilding industry, a large share of the consumed resources is manpower -- both managerial and waterfront craftsmen. Despite major technological advances over the past fifty years, it is becoming increasingly more difficult to generate large productivity improvements purely through technology. Combined with the fact

that the current economic and fiscal situation is precluding large capital improvements in equipment and facilities, most shipyards must look to better human resources management as their best hope for improving productivity.

> A major input to the productivity ratio is the whole area of ulitization of human resources. Historically, efforts to improve human resource productivity have focused on asking for "more". Employees have been pressured to work harder and increase their output. In recent years, however, the potential for gains from this strategy has been blunted by legislation, unions and social norms which no longer permit the "sweatshop" mentality in our business and commerical institutions. As a result, most efforts to increase human resource productivity have come to focus more on the inputs: cutting back staffing levels as much as possible; replacing people by less expensive equipment; and so forth. People are seen as a direct expense, and productivity can be, achieved by cutting this expense as much as possible.

This management attitude inevitably leads to worker resentment and work slowdown. Likewise, workers tend to view changes toward productivity improvement from managers who feel their work force is only another "direct expense" as tricks or ways to ease them out of a job.

However, many enlightened organizations are beginning to recognize a relatively new area for increasing productivity of the human resource without reducing the inputs. They are discovering that by designing new systems and managing the job with a more enlightened human resource management approach, that the workers' output increases without the necessity of working harder. In other words, these forward-thinking organizations are rediscovering the truth of the old adage, "Work smarter, not harder." This concept also applies to management and project organizations as much as it does to a waterfront welding team. As will be explained later in this paper, more enlightened use of managerial expertise in the earlier stages of the shipbuilding project can go far in alleviating construction problems for the crafts on the ship and, thus, aid in improving productivity. In a recent presentation to the Panel on Navy Shipbuilding at the University of Virginia, Mr. William E. Haggett, president of Bath Iron Works, emphasized this by asserting that "the key to achieving shipbuilding performance improvements begins with Management."

[1] John R. Hinrichs, Practical Management for Productivity. (New York: Van Nostrand Rinhold Co, 1978), P. x-xi.

[2] William E. Haggett, "Executing the Navy's Surface Combatant Shipbuilding Program," Sixth Annual Seminar of the Center for Oceans Law and Policy, University of Virginia, January 16, 1982.

A survey of recent developments in productivity and the changes occuring in the working place indicate that productivity changes are begun at the management and supervisory level. The Work in American Institute listed this new focus as:

> Concepts of new job design which uses team work and project organizations to capitalize and maximize the strong points of the individual and builds upon the synergy of the group.
>
> Increased effective use of incentives and feedback to increase productivity where more goal-setting processes are being applied at all levels.
>
> Improved human resource productivity as characterized by a participative management approach that recognizes most employees as responsible mature adults who react positively to the opportunity to have some degree of voice in their own destiny. This idea is one whose time has come and requires the development of management approaches that build employee involvement and shared objectives.

As can be seen from this, the thrust of current productivity improvements center around more effective planning and the increasing involvement by both management and workers to jointly address productivity issues. This also reflects the changing social norms and make-up in the working place. There is an ever decreasing gap between the educational and intelligence level of the work force and management. Similarily, as the cost of technology spirals upward and the price of new capital investments becomes ever more prohibitive, organizations begin to realize that worker productivity will have even more of an impact on revenues and, thus, profits. The old concern as to how a production effort will effect profits is being replaced with growing concern about its affects upon the work force. As Haggett so rightfully noted:

> Perhaps this change in attitude from the 1960's and 197O's to where management is now saying, "We will work together to achieve program goals and objectives," is the most significant reformation that has taken place in our industry -- for without this attitudinal change, other reforms could not hope to produce desired improvements.

Unfortunately, the United States is late at realizing this. Japan's climb to the top of the industrial world has been greatly enhanced by its quality goals, achieved through such techniques as Quality Circles and management concern for employee welfare. And, this growth is aided by management realizing that the best point of attack for improving productivity is a

[3] Hinrichs, p. xii.

[4] Haggett, p. 4.

knowledgeable, dedicated, and technically competent first level supervisor. Likewise, while other Western countries were showing declines in productivity and growing labor unrest, Germany was improving its productivity annually. This fact was aided by such innovative measures as goal setting at the shop level and participative decision making by both union and management.

Applications of these concepts need not be left to just elements within an industry but could and should be applied to all areas where team work and joint concern for a project's welfare are common. This definitely includes the government/DoD contracting arena, especially in those areas such as shipbuilding, where joint efforts in R&D, design, and weapon systems integration require the utmost in cooperation. In the Navy shipbuildinng process there are three major areas where productivity issues are most frequently encountered. These areas involve (1) the organization that plans and designs the project, (2) management of the ship production process, and (3) the management of the program itself, especially as it applies between shipbuilder and Navy Project management.

## Organizational Development

Jay Galbraith, in his definitive study of complex organization designs, put forth the theory that "observed variations in organizational forms are actually variations in the strategies of organizations to (1) increase their ability to preplan, (2) increase their flexibility to adapt to their inability to preplan, or (3) decrease the level of performance required for continued viability." He goes on to stress that the driving force to such organizational designs is the necessity to process information which will facilitate task accomplishment. "As the volume of information becomes substantial, the organization either finds ways to process the information or discovers ways to avoid having to do so." Thus, in a decentralized and loosely organized organization, key informational elements and data may be overlooked, or, the necessary information may not be processed to the right managers for action and inclusion in its goals or objectives.

This problem definitely can occur during the design phase of a new shipbuilding project as the degree of informational uncertainity increases. Galbraith defines uncertainity as it relates to organizational design as "the relative amount of information that must be acquired during task performance. It is relative to the amount of iqformation required and the amount already possessed by the organization." Consequently, if the expertise pertaining to the producibility of the ship is not apparent or

[5] Jay Galbraith, Designing Complex Organizations. (Reading, MA: Addison-Wesley Publishing Co., 1973), p. 4.

[6] Galbraith, p. 6.

7 Galbraith, p. 5.

savailable during the design phase, then productivity will not be adequately considered at that time. This would be a result of this issue being "O.B.E." due to the gaps in technical information and compressed design schedule. Consequently, poor design phase organizational development adversely affects the downstream production proccess.

## Management of the Production Process

The best control and development of productivity lies in the ability of the water-front supervisors. This is in keeping with Galbraith's four alternatives to reduce the degree of uncertainty (as shown by the information that has to be processed). This process is based upon improved lateral relations where lower level managers solve the problem at their own level by contacting and cooperating with their peers instead of referring it upward in the managerial heirarchy. However, in order for this to happen at the lower supervisory level, the organization must ensure that as much knowledge and understanding of the goals and objectives of the production process is made available to their waterfront supervisors. The success of Japan's Quality Circle program is a derivative of this concept. The production process must be adequately engineered and planned before the lateral relations concept can be successfully applied. Likewise, the first line supervisor must be thoroughly trained and possess the required managerial skills to resolve problems, motivate the workers, and coordinate with his peers. The result of this would be the placing of responsibility for productivity improvements at the level where productivity occurs. The end result would be a decrease in informational processing and corrective actions by upper level managers, thereby freeing more of their valuable time to developing better engineering plans and ensuring that the waterfront supervisors have the best design packages to work with. Similarily, these upper level managers will be better able to address major issues whose resolution involve more intricate and complex coordinating among the work force.

## Management of the Project

One of the major problems affecting both cost and schedule of modern weapon systems acquisition is the concurrency of development and production required to meet both time and fiscal constraints. The successful resolution of this demands more customer (in this case, the government and contractor) cooperation, understanding and involvement. In its attempts to meet the strategic and tactical specifications for its weapon system, military agencies are constantly evaluating the technology and designs for its equipment. Unless there is cooperation between the manufacturer and the government sponsor, this constant change process will have adverse impacts on both planning and productivity, not to mention cost. Just as it is important to have the most competent and knowlegeable team developing the ship design, it is just as crucial to have the proper technical expertise in the Navy project organization to ensure that budget and engineering change proposals will not impact the productivity improvements gained from the prior design planning phase and from the placing of top notch supervisors at the waterfront. Experience has shown that even when design engineering gets an acceptable package down to the waterfront,

a high percentage of Navy required rework due to ECPs results in both lost time and man-hours. This culminates in frustration for the work teams who receive no credit toward construction progress or goals as a result. Qualified ship production engineers must be an integral part of the Navy's management process in order for the Navy to actively contribute to productivity instead of becoming a hinderance.

## II PRODUCTIVITY ISSUES

As has been previously discussed, productivity improvements must be initiated at the management level. Part of the problem in improving productivity lies in creating an awareness of the areas where productivity is being impacted, whether through organizational design, informational overload, lack of properly trained managers at the waterfront level, or inexperienced technical insight as to impacts caused by program decisions. Three areas where productivity issues are apparent are the (1) early design phases, (2) Navy project management, and (3) waterfront management relationships with the shipbuilder.

### Design Development Issues

As Hinrichs pointed out, effective job design encompasses putting the proper skill mix together so that there is a balanced use of an organization's human resources. Galbraith stressed the importance of effective organizational development such that resolution of uncertainty is achieved at the lowest levels, thereby freeing an organization's upper levels to address more global issues. These components of productivity have direct application in the Navy's ship design community where frequently concern for producibility in design is often overtaken by more pressing demands of schedule and systems integration goals. William Haggett, president of Bath Iron Works, feels strongly that by placing emphasis on developing productivity enhanced designs, it will contribute greatly to the overall performance in ship construction: "We are convinced that more producibility emphasis in the Navy's early design[8] process is not only desireable but feasible given present technology." He goes further to state that such efforts will result in more cost effective ships which will be built in less time and requiring less from the more skilled construction workers. And, since most of a work force's skilled craftsmen are frequently in a supervisory role, this will also allow them to spend more time on productivity improvements at their level.

In addition to Galbraith's studies on organizational development and its impact on informational processing, other studies have also highlighted the fact that an organization's hierarchical structure acts as a hinderance or aid to resolving problems and addressing major issues. In a decentralized organization, as exsists where various projects are ongoing simultaneously, an informational processing gap exists between the upper

[8] Hinrichs, p. xi.

[9] Haggett, p. 7.

and lower levels of management. The ability and resourcefulness of the teams working on the individual projects are not benefitted by a definite and concise set of objectives and priorities. Likewise, the approach to each team's task is ultimately flavored by the individual technical talent within each group. Unless upper level management takes the initiative to establish the overall goals and objectives for the organization, especially as they pertain to productivity, then there will be little or no lateral contact on this, as well as possible informational overload in the upper levels resulting from the vertical passing of problems upward for resolution. The Navy design community can ill afford to overlook such critical issues as productivity impacts of designs simply because it does not have the proper technical team mix or an inadequate structure to address the major production planning issues and objectives. Failure to involve knowledgeable and technically experienced production engineers in the design phase has resulted in short-sighted designs, whose schedule has been met, but has caused delays, rework, and frustration in the shipyard. This aspect of the design phase failure to evaluate productivity impacts will have a ripple effect throughout the production process. The engineering department, if it is properly considering producibility, will have to review and identify those areas requiring redesign. This in turn will impact the timely submission of producible plans to the waterfront. Those areas not properly identified and corrected will result in unnecessary rework and delays by the craftsmen. This in turn will cause the ship's work force to waste valuable time and energy that results in lost opportunity for them to gain on their own productivity goals. And, since rework results in 0% contribution to physical progress, the overall schedule progress of the vessel under construction will suffer. Finally, the Navy winds up paying for labor to correct design deficiencies that may have been contributed by its own design community. But, more importantly, the morale and efficiency of the work force will suffer. This loss in motivation could conceivably carry over into other aspects of the construction process and further erode productivity goals. As Mr. Haggett so aptly states, "With quality work performed on the front-end, even average mechanics can succeed, but if front-end work is mediocre, the best mechanics in the world cannot produce a high quality ship at low cost and on schedule Truly, front end performance has a huge impact on final results."

## Shipyard Management Issues

When human resource management began to gain attention as a more likely approach to motivate employees, and thus improve productivity, several theories evolved that point out the basic requirements to this technique. McGregor's Theory Y (1957) maintained that the lack of employee motivation can not be cured purely through the outdated management control of reward (e.g. money) and punishment, but by management's attempts to provide a more participative and humane environment. Maslow's (1954) earlier work on need heirarchy supported the development of Theory Y by asserting that a man is motivated by basic needs which exist and can be

[10] Haggett, p. 6.

fulfilled through work. This important concept implies that work is a critical means by which a person's life goals can be realized. Consequently, if management establishes working conditions and environments to meet these physiological and psychological needs, workers will be more motivated and dedicated to realizing the organization's goals, such as improving productivity. These major post-war changes have had significant impact upon how an organization performs, and reflects the increasing mental and technical capabilities of the modern work force. Today's work force not only wants to feel an integral part of the overall project, but, has the ability to see where management is not doing its share as far as planning and supervising the efforts to reach goals and objectives. More recently, Dr. Edwin Locke at the Science of Productivity Conference in 1981 put forth a more up to date view in what he terms as Theory V, reflecting the more recent developments in work motivation. Theory V addresses the role of needs and values in guiding action; the role of value attainment in job satisfaction and productivity; the role of money and goal setting as motivation of job performance; techniques for motivating the utilization of knowledge in implementing goals; and the role of social factors as motivators and demotivators of job performance. All this attention and academic research point up to an organization recognizing that the leadership and motivation of its work force represents its best resource for producing at more productive levels and cost effective manners. The most visible example of this is again the practice shown by Japan. Here, the crux of all management initiatives and plans are based upon the team leaders on the plant floor. These team leaders organize and supervise their fellow employees to accomplish goals and objectives which they have established to accomplish the company's plan. There is considerable formal interaction between management and the work force through these supervisors and their Quality Circles (QC) groups. This approach has definitely benefitted Japan with products of the highest calibre and cost effective production.

With these new ideas in mind, the shipyard management will come to see that the most critical element in productivity improvements is the waterfront first line supervisor. This person represents the shipbuilder's most important investment in meeting schedules, resolving issues, and motivating the workforce. The mechanic on the waterfront has had, out of necessity, to become more technically capable to accomplish the highly complex tasks required of the Navy man-of-war. This new breed of shipyard worker is no longer just satisfied to make ends meet; he or she is looking for benefits, better working conditions and a leadership to which they can relate. Based upon his or her technical expertise, the first line supervisor is responsible for translating plans into sub-systems which eventually provide a very complex man-of-war. The first indication of problems in the designs of work packages will be most likely identified by this person. Because the supervisor works directly with the work force, he is the most capable of understanding their problems and difficulties, and resolving these roadblocks to productivity. The lowest level manager working with the work force represents the image and understanding that ship's labor have of shipyard management and its ability to plan effectively.

[11] Dr. Edwin A. Locke, "A New Look at Work Motivation: Theory V." Presentation at the Science of Productivity Conference, Washington, D.C. November 1981.

The changing nature of the modern work force requires that managers be more attuned to the human side of labor and be more sensitive to their needs and work requirements. The current work force is more intelligent and perceptive to poor management as displayed through their planning and control capabilities. Today's work force is more motivated by participative management than the traditional authoritarian approach. The best technician or skilled craftsman may not always represent the best supervisor. In addition to losing a productive worker by promoting to management positions, productivity may be further impacted by the lack of management skills he or she possess. Shipyard managers must evaluate their potential supervisors as to their ability to apply two dimensional thinking; to plan and resolve problems, and, more importantly, their capacity to be decisive and innovative toward productivity goals.

Inefficient or poor first level management creates more problems for the subsequent levels of shipyard management. The first level manager must be capable of understanding and carrying out the goals and objectives of the ship construction process. Concentrating only on the immediate work is one dimensional and prohibits long term productivity gains. If upper level management fails to involve the waterfront supervisors in the company's goals and objectives, these people will not be able to translate such objectives to the work force which ultimately is responsible for the achievement of those goals. Upper level management which fails to appreciate the impact that waterfront supervision has upon productivity will invariably be contributing to the failure to achieve their own objectives. Upper level managers are charged with providing both structure and information to the lower level management team. Failure to rely upon the more skilled waterfront supervisor to solve technical problems will cause non-productive solutions and possible decreases in motivation and morale. Failure to involve waterfront supervisors in the planning process also lends itself to inefficiency and non-productive goals as well as setting the stage for further construction problems. Galbraith highlighted this fact in his analysis on making lateral processes effective and improving project organizations:

> At least a substantial minority of the work force must consist of managers who will subsequently be held responsible for the implementation of the project plans and goals ... the participation of line managers is essential if task forces or teams are to reduce information overlaods. This means the group must arrive at an action decision. Therefore, the manager who is responsible for implementing the action, must participate... If an action decision is to be reached, the participants must have the information relevant to the decisions with which the group is charged. The appropriate solution is to have lower-level personnel represent the department. These people are usually first - and second-level technical people. They are the ones in day-to-day contact with the technology and techniques .

[12] Galbraith, p. 55-57.

Navy Management Issues

The structure and organizational design of a Navy Project Office lends itself to the development of good technical and participative management approaches. A Navy Project Office compares favorably to the three basic design strategies Galbraith maintains will provide sufficient impetus to successful task completions. Thus, a typical shipbuilding project office is based upon:

- the creation of self contained tasks (such as the ILS or Production Management sections) which concentrate their efforts on specific technical issues,

- investments in various vertical information systems (such as a production information management system or project risk systems),

- and, the encouraging of lateral relationships, (as shown by the interactions between sections as well as between project managers and their peers at both the shipyard and SUPSHIP).

However, whenever understaffing or poor planning weakens one of these elements, as happens when technically less qualified managers fill the production management position, then even the best intentions can result in complications with productivity plans. Navy managers who try to forcibly "direct" their areas of the project without fully understanding the nature and problems of shipbuilding processes often complicate the attempts to improve productivity. Quick fixes and decisions on potential problems without more comprehensive analyses that are forced on the shipbuilder will invariably defeat any long term gains. Navy project managers must establish solid team relationships with their shipyard counterparts and work together to resolve issues leading to successful productivity. Adversarial roles only break down communication and lower morale.

Navy management, through neglect of proper production planning, finds themselves spending more of their time trying to explain schedule slippages and cost overruns than concentrating on how the Navy and the shipbuilder, together, can stick to and achieve their schedule and budget goals. Failure to adequately understand shipbuilding production processes will lay the foundation for making counter productive judgements concerning design and construction options.

In addition to possessing sufficient technical knowledge, Navy managers who do not have a systematic and thorough data analysis and problem identification process will not be able to fully capitalize on the abundant data and information they receive. This in turn will prohibit their understanding of the production process. Also, unless Navy managers establish a good and solid working relationship with the shipbuilder's

[13] Galbraith, p. 19.
[14] Ibid., p. 15.

managers, the quality and quantity of their information is subject to decline as a result of a lack of understanding of the Navy manager's needs and of poor communication. Navy managers must possess a comparable level of expertise with their shipbuilder counterparts or the communication process so vital to good team work will never materialize. This aspect cuts across the entire spectrum of knowledgeable exchange and joint resolution of problems affecting productivity.

## III SUMMARY

Increasingly greater emphasis is being placed upon improving productivity through innovative management techniques. To be able to achieve these improvements, management must adopt a more humanistic approach with their work force, develop participative environments, and further develop their technical expertise in order to facilitate the overall communication process.

We have not sufficiently recognized the direct relationship of human factors engineering and motivation on productivity. "The results of these conditions in the labor market of Japan are that shipyard workers are company-oriented, committed to long term employment, and highy regarded by their peers. High worker productivity can therefore be understood... Without consideration of these vital elements, centered around humane use of human beings, any assessment of shipbuilding technology, functional management, and production processes, will find only partial definition the system under review with incomplete findings and conclusions.** three critical areas where these factors can be addressed are in the engineering design, production and Navy management phases. The issues identified in this paper can all be related to impacting productivity and are subject to change for the better if productivity and sound management can be embraced as a single entity.

[15] Raymond Ramsay, "A Time for Shipbuilding Renaissance," Paper for The North East Coast Institution of Engineers & Shipbuilders, England, 1982. p. 37.

NSRP 0009
Paper # 24

# MAPLIS: AN ON-LINE MATERIALS RESOURCE PLANNING SYSTEM TAILORED TO THE SHIPBUILDING AND OFFSHORE INDUSTRY

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## ABSTRACT

MAPLIS is an on-line computer system for material management in yards building ships and offshore constructions. It consists of five modules or subprograms which may be installed separately or together as one integrated system. Material planning and control in MAPLIS starts in the design office with drawing files, material specification and purchase requests, continues with purchase orders, expediting, receiving, storage status and cost control and ends in work preparation with work orders, drawings and bill of materials. The system handles outfit and steel materials, both direct and stock items.

Fig.1 . MAPLIS Materials Resource Planning Svstem

As indicated in the title of this paper MAPLIS is a computer system developed to suit the material management procedures in yards dealing with new building or repair of ships or offshore constructions. MAPLIS is project oriented, it is particularly suitable for follow up of direct ordered materials and allows a detailed product breakdown for cost control purposes.

Fig. 2. MAPLIS Projects.

The ships and platforms showed on this figure have at least one thing in common: The material management and control has been handled by MAPLIS. The system is flexible in the sense that it may be used on several levels of detailing, depending on the requirements. It is well suited for traditional shipbuilding, but it will also satisfy the strict follow up and documentation requirements in offshore and navy projects.

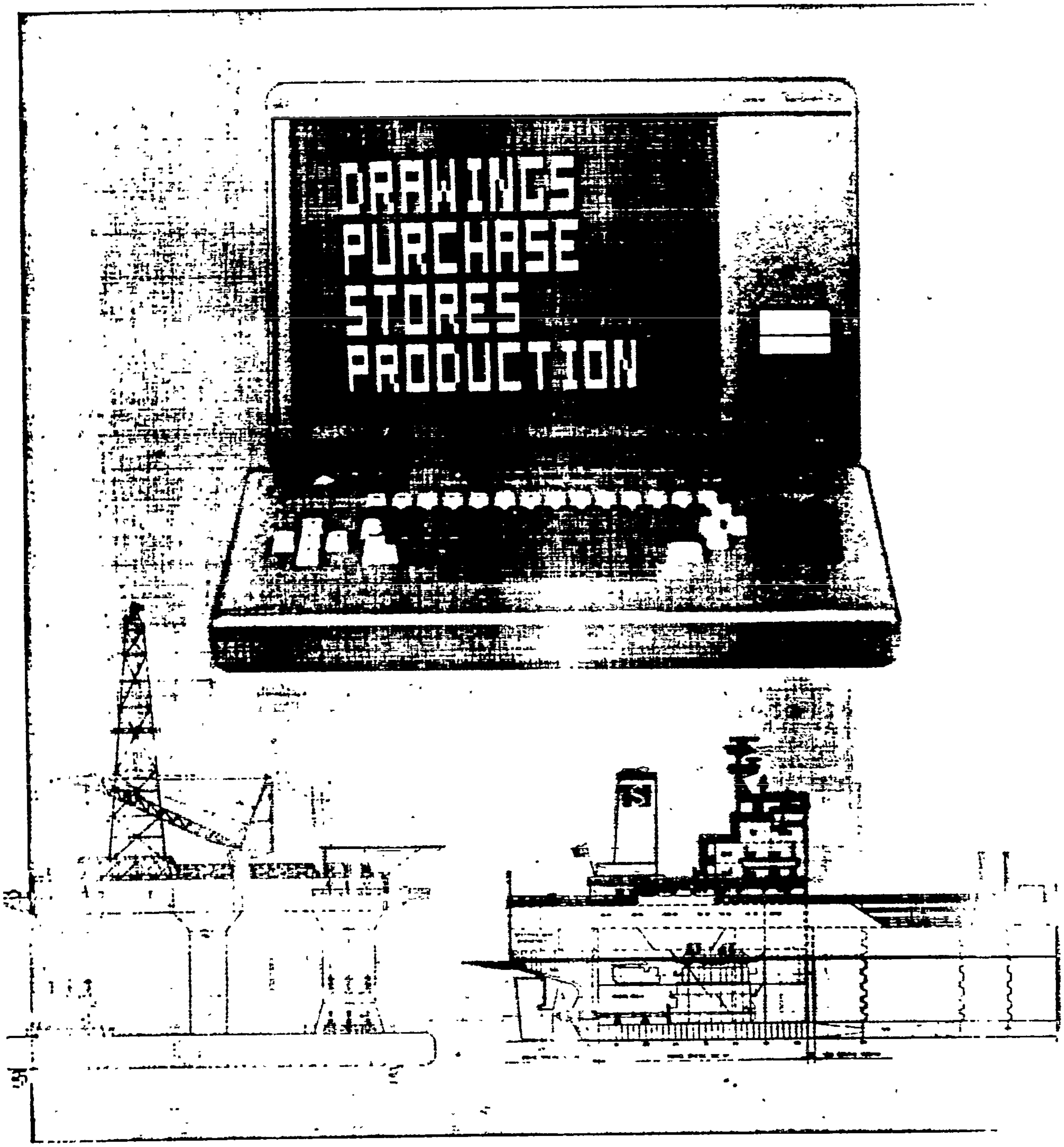
Fig 3. MAPLIS modules and functions

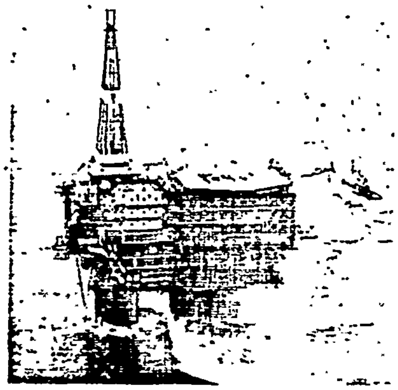
MAPLIS consists of 5 different modules, each comprising a logical set of management functions. Each module may be used separately. Together they work as one integrated system, communicating through a common database.
In MAPLIS the term 'material management' means more than purchasing and warehouse control. Also the design and work preparation functions are involved.
MAPLIS is a tool both for detailed physical follow up of materials and complete cost control for one or several projects.

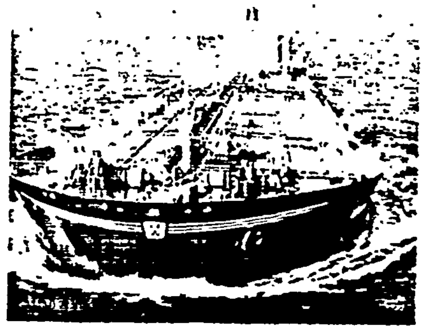
Fig. 4. Information flow in the vard

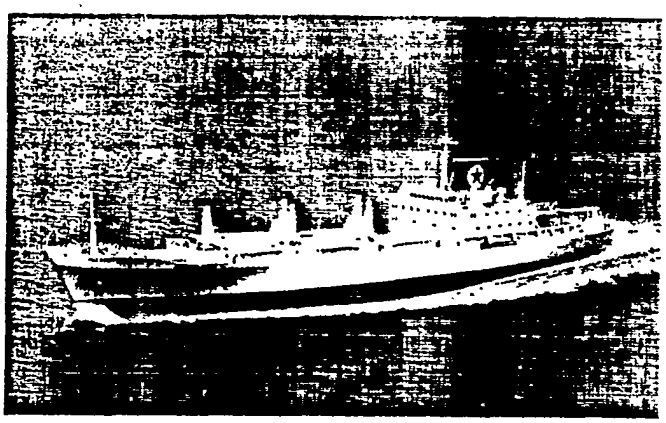
The information flow between departments using MAPLIS does not differ from standard shipyard practice. The difference lies in the fact that all departments involved have instant access to up to date information in the database, and that paperwork is reduced to a minimum.

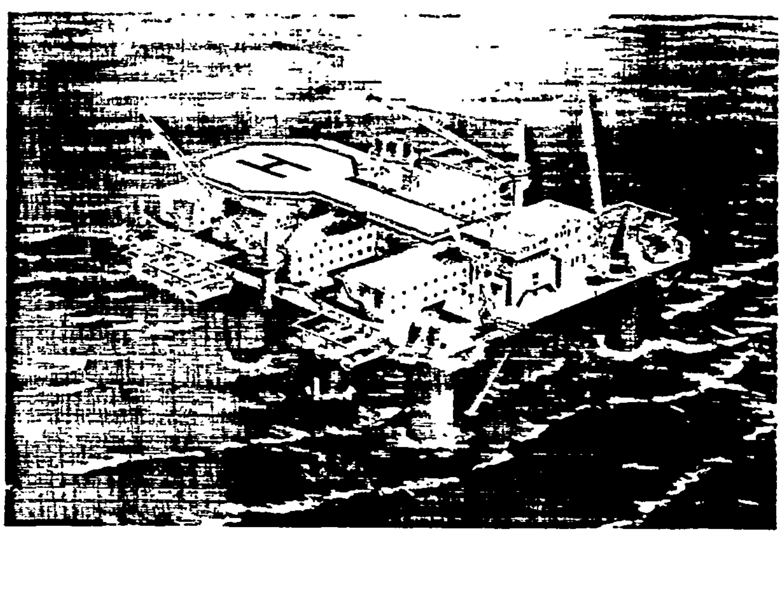
# MATERIALS ADMINISTRATION SYS



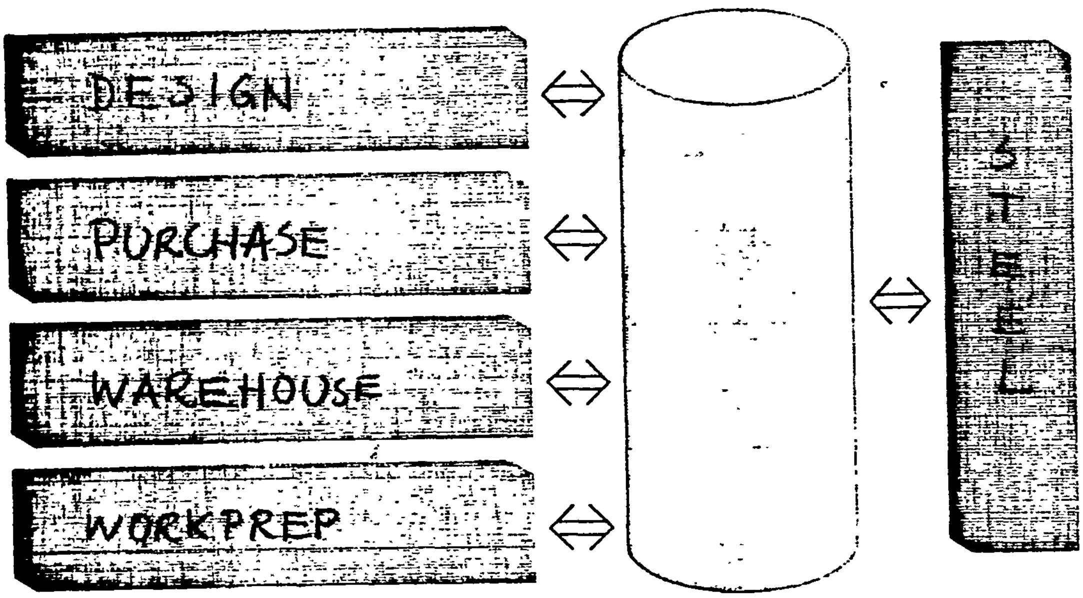








# MAPLIS MODULES



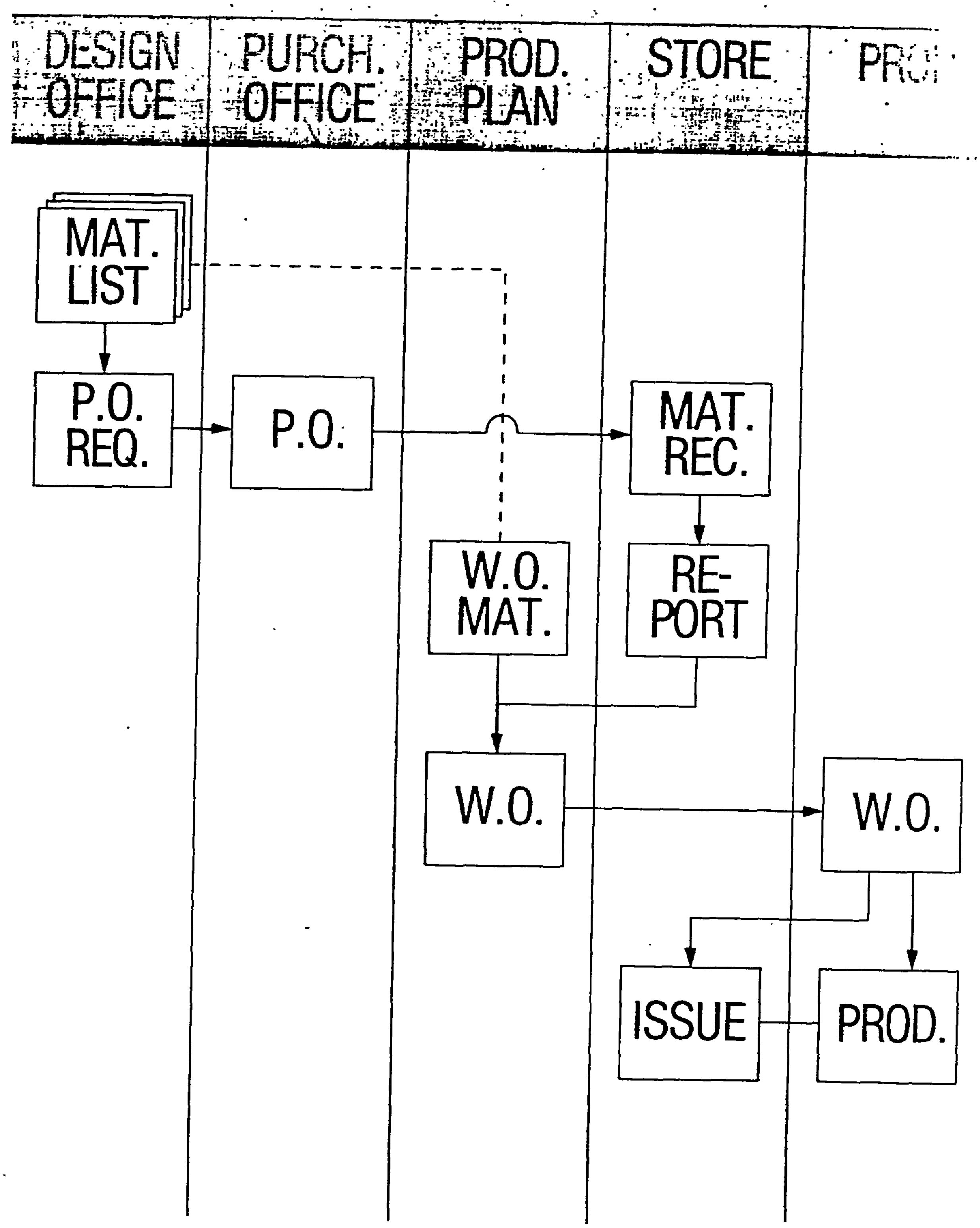

DESIGN OFFICE
PURCH. OFFICE
PROD. PLAN
STORE
MAT. LIST
P.O. REQ.
P.O.
MAT. REC.
W.O. MAT.
RE-PORT
W.O.
W.O.
ISSUE
PROD.

**Fig.** 5. Hardware configuration

The terminal (alphanumeric display) will be the 'work station' for personnel daily engaged with MAPLIS. This means that terminals must be distributed in the departments in sufficient number to allow easy access to the system. The standard version of MAPLIS is delivered on PRIME minicomputers.

**Fig. 6.** The DESIGN module

This module serves two main purposes in the design office as shown on the figure. The drawing register keeps a record of the drawings with related key data items. The other function is material specification. Material lists are defined per drawing.

**Fig. 7. The** drawing register

The figure shows data items filed in the drawing register. The system also keeps track of the revision history of each drawing, from the first to the last revision. Each of the date items may be used as sorting key for drawing reports.

**Fig 8. Material**

The lists are written line by line just as one does manually on a drawing. It is possible to modify or expand the lists in the database at any time. Once the material list is stored in the system, it may be displayed on the terminal or on the printer.

**Fig** 9. Planned to CAD/CAM systems

The next step in our development, which is scheduled for **1983,** is to link MAPLIS to the AUTOKON (steel) and AUTOFIT (piping) systems. The material 'take off' from these systems may then be transferred directly to MAPLIS through a 'material take off' communication program.

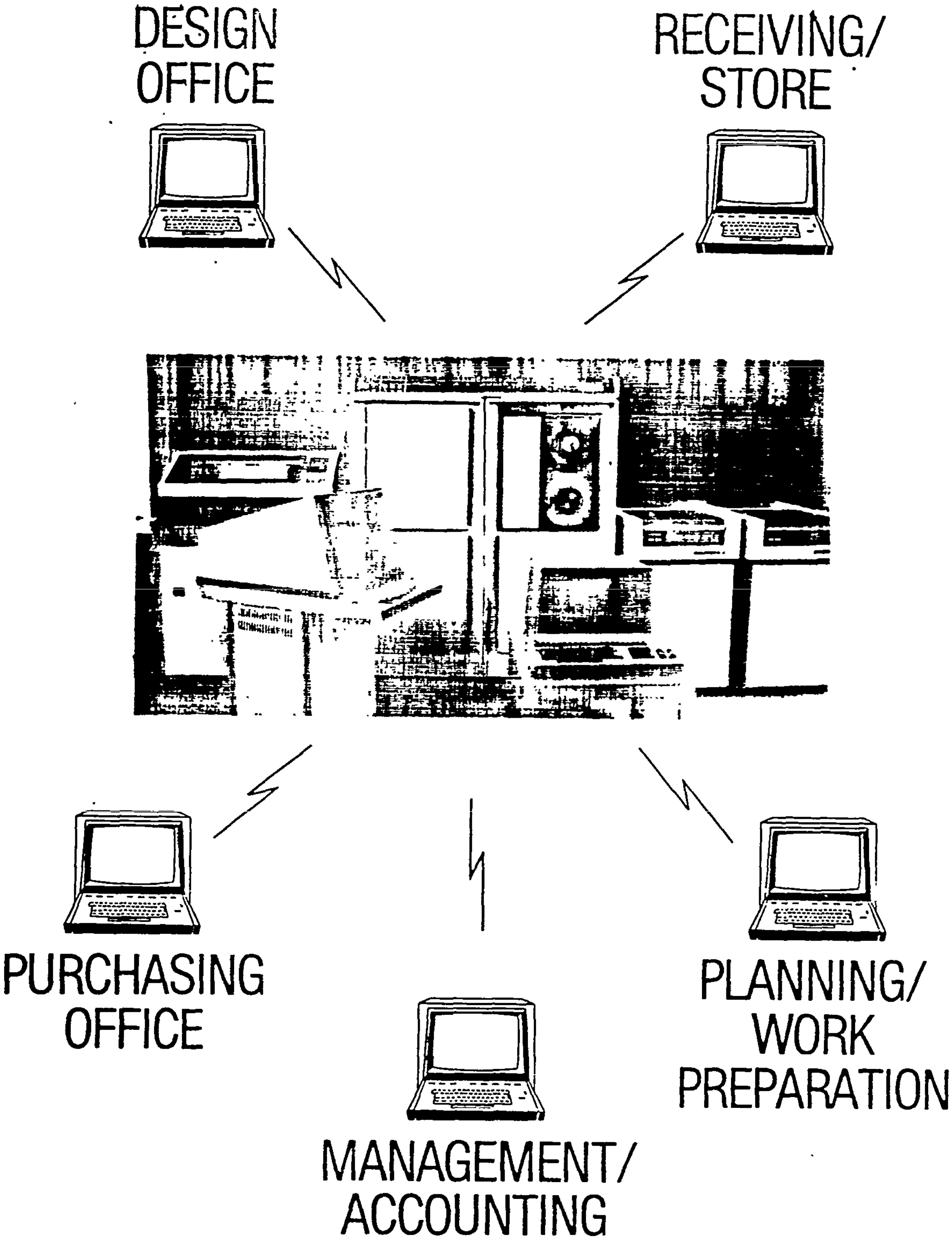

DESIGN
OFFICE
RECEIVING/
STORE
PURCHASING
OFFICE
PLANNING/
WORK
PREPARATION
MANAGEMENT/
ACCOUNTING

Fig. IO. The PURCHASE module

All purchases of direct materials or warehouse items goes through this module. The expediting and receiving functions are also included here, and the module gives cost control reports either per project or combined for all projects. The module keeps track of direct materials from the vendor, through receiving, storage and issuing into production.

Fig. 11. Purchase Orders (P.O.'s)

The purchase orders are edited on the display, when completed they are printed on P.O. forms (snap-sets), ready for mailing. The system allows several payment dates per P.O. and separate delivery date and currency per P.O. item. It is also possible to distinguish between calculated and order confirmed prices. It is possible to describe each item with unlimited text.

Fig. 12. Expediting and receiving

The expediting process using NAPLIS is, as shown in the figure, basically similar to the standard manual procedure.

MAPLIS gives automatic warnings for P.O. reminders after a plan predefined by the users themselves. The intensity of expediting is decided for each P.O. The system allows separate follow up of P.O. items and related certificates. The expediter may at any time use the database as a ‘notebook', i.e. he may write text with messages concerning the vendor or P.O. status. This text may then be available as information for other yard functions.

Receiving of materials are also entered on a display, with direct reference to the P.O. items concerned. The receiving personnel also has the possibility to enter text messages in the system, f.inst. if any damages are discovered. The system handles part deliveries of P.O. items.

This module also handles issuing of direct materials for production. The system will give complete documentation for each project concerning direct materials ordered, received, issued, as well as a survey of surplus materials left on the site (quantity and location).

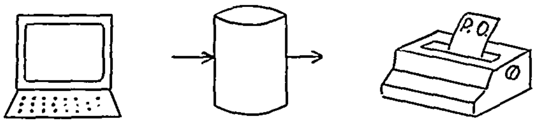
**PURCHASE**

**FUNCTIONS**

- PURCHASE ORDERS
- EXPEDITING
- RECEIVING
- COST CONTROL

**PURCHASE**

**PURCHASE ORDERS**




- UNLIMITED TEXT
- CURRENCY, PRICE, DEL. TIME PER P.O. ITEM
- SEVERAL PAYMENT DATES PER P.O.
- CONFIRM./ESTIM. PRICES

**PURCHASE**

**EXPEDITING**

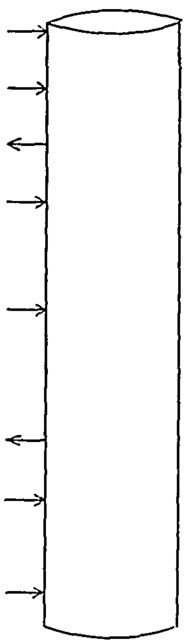
- ENTER P.O. →
- ORDER CONFIRM. →
- VENDOR WARN. ←
- " ANSW. →

⋮

- MAT. DELIVERY (TOTAL/PART) →
- VENDOR REMIND. ←
- " ANSW. →

⋮

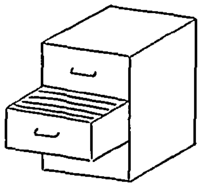
- ISSUES →



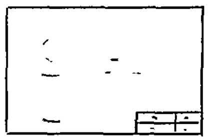
# DESIGN

## FUNCTIONS

- DRAWING FILES



- MATERIAL SPECIFICATION




# DESIGN:

## DRAWING FILE INFO

- PROJECT NO. (HULL NO.)
- DRAWING NO.
- FILE IDENT. (ORIG., COPY)
- REVISION NO., DATE
- AREA, LINE, GROUP NO.
- RECEIVING DATE
- DISTRIBUTION INFO.
- DRAWING TEXT

## DESIGN :

**MATERIAL LISTS**

- ONE LIST PER DRAWING
- ONE LINE PER ITEM
- PREFAB., INSTALL.
- RESERV. STOCK ITEMS
- ALLOC. OF P.O. ITEMS
- MODIFICATION
- P.O. REQUISITION

## DESIGN

**PLANNED LINK TO CAD/CAM SYSTEMS**

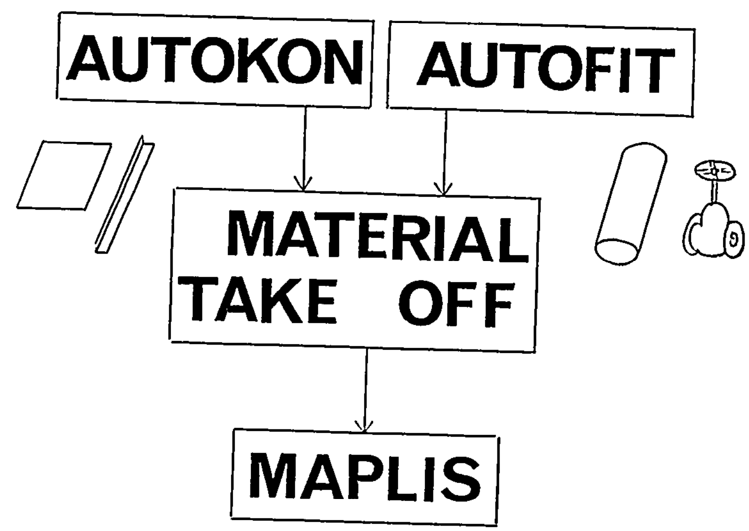


Fig. 13. Material cost control

The price information (calculated or confirmed) in the P.O.'s may be used to report payment forecasts for chosen periods.

Vendor invoice information is entered into the system, and the invoice items may be checked against the related P.O. items.

The system has numerous report alternatives for payment status, project cost accounts and vendor oriented accounts, all based on ordered and invoiced prices.

Fig. 14. Material traceability

The trend in offshore projects (and also navy projects) points towards stricter requirements concerning material traceability. This applies mainly to steel products (plates, pipes). MAPLIS is now prepared to follow such items from the steelmill (each item marked with a 'charge' or 'melt' no.), through intermediate storage, receiving at the site and installation in the finished product. This means that the P.O. item level, which has been the lowest level so far in the P.O.'s, is split into a sub-item description. F.inst. one P.O. item consisting of 2 pipes with equal dimensions and qualities, but different charge no's, is split into 2 different sub-items.

Fig. 15. The WAREHOUSE module

This module controls the standard warehouse or stock items. The module requires that some kind of stock item code is used.

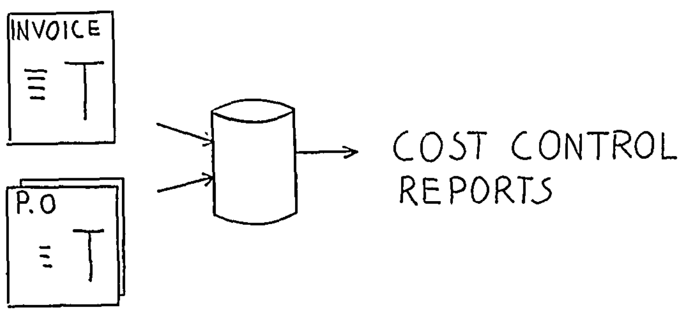
Fig. 16. stock level control

Each stock item is described with a code, name, dimensions, order point, price etc. The stock level is adjusted by entering information about issues, items returned to the warehouse, returned to vendor or reserved by the production departments. Automatic order impulses are given when available stock level gets below the defined order point. Consumption reports are given in many different alternatives. ARC-analysis based on consumed volume is possible.

## PURCHASE

## MATERIAL COST CONTROL

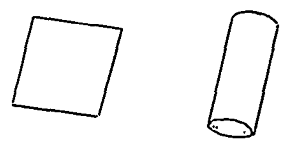
- PAYMENT FORECAST
- INVOICE CONTROL
- PAYMENT STATUS
- PROJECT COST ACCOUNT
- VENDOR STATUS




## PURCHASE

## MATERIAL TRACEABILITY

MANUFACTURER



CHARGE NO.

↓

RECEIVING

↓

WORK PREP.

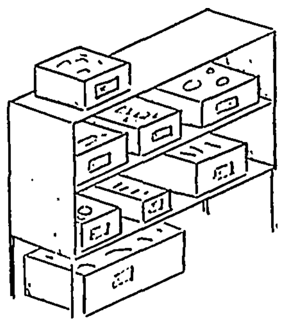
↓

INSTALLATION

## WAREHOUSE

### FUNCTIONS

- STOCK LEVEL CONTROL
- WAREHOUSE CATALOGUE
- COST REPORTS
- ITEM STRUCTURES



## WAREHOUSE

### STOCK LEVEL CONTROL

- ITEM DESCRIPTION
- ISSUE, RESERV., RETURN
- CONSUM. REPORTS
- P.O. IMPULSE
- ABC-ANALYSIS

Fig. 17. The WORKPREP module

This module is a tool for preparing a work order with related drawings and materials (the work order scheduling is not done here).

Fig. 18. Assign materials

To have full benefit from this module it is required that the pertaining drawing material lists are stored previously in the database. The bill of materials for a work order is then composed by manipulating these lists. A drawing list may be split between several work orders. Even a line (item) in a drawing list may be split this way. When the bill of materials is completed, it may be printed and used as a requisition for issuing.

Fig. 19. The STEEL module

Steel plates and bars in standard formats are handled by the DESIGN, PURCHASE, WAREHOUSE and WORKPREP modules just like any other item. But in the case of 'tailored' steel specifications the task is a little different. A large number or non-standard formats requires extensive sorting, marking and pricing routines. The STEEL module is made for this purpose, and combines in a way the properties of the other 4 modules. The actual purchase order for the steel materials are prepared in the PURCHASE module.

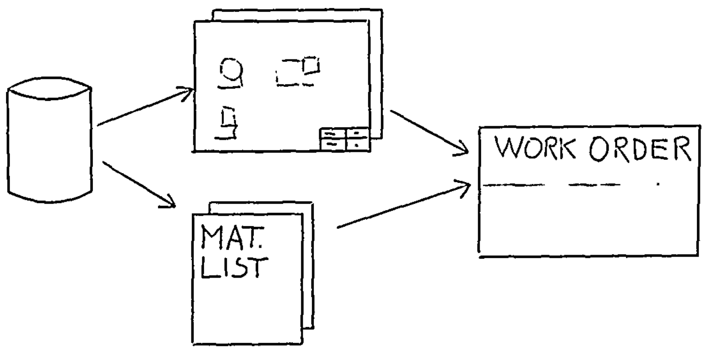
Fig. 20. Specification/ordering

In order to rationalize the specification task it is possible to prepare a library in the database consisting of steel quality codes (classification codes), bar section standards and overprice tables.
The specification (plates/bars) is done block by block, and marking no's are given automatically. Before preparing the purchase order, it is possible to run 'price simulations'. Through variation of the steel formats it is possible to find a near minimum price level.
It is possible to prepare a storage (piling) plan already at the time of ordering. This must be made according to a steel production plan.

# WORKPREP

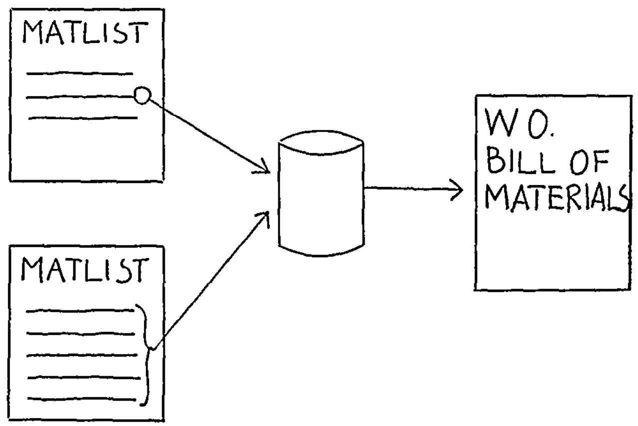
## FUNCTIONS

DEFINE W.ORDER
- ASSIGN DRAWINGS
- ALLOCATE MATERIALS




# WORKPREP

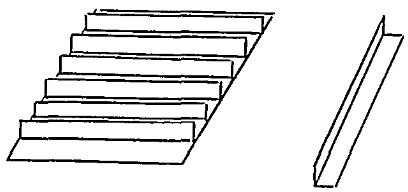
## ALLOCAT. MATERIALS



## STEEL

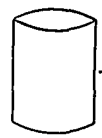
### FUNCTIONS

- SPECIFICATION
- RECEIVING, STORAGE
- ENTRY INTO PROD.
- STEEL CONSUMPTION



## STEEL

### SPECIFICATION



QUALITIES
STANDARDS
PRICE STRUCTURE

BLOCK LISTS

AUTOMATIC MARKING

PRICE SIMULATIONS

STORAGE PLAN

Fig. 21. Receiving, storage, production

STEEL is used to check received materials against the P.O., and then to monitor the piling in the storage area and entry into production. It is also possible to specify steel part list in STEEL, and link a charge no. to each part. STEEL will provide complete consumption reports for each project.

**STEEL**

**RECEIV.,STORAGE,PROD**

**RECEIV. CONTROL**

**PILING**

**ENTRY PREFAB.**

**PART LISTS**

0009 #25

# CLASSIFICATION AND CODING: A TOOL TO ORGANIZE INFORMATION

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Organization for Industrial Research Incorporated
Waltham, Massachusetts

Mr. Houtzeel has 20) years. of experience in engineering and management. He established the American office of TNO, The Netherlands, in 1970. He has been a pioneer in the introduction of Group Technology to the United States. Prior to joining TNO, Houtzeel was a Project Leader at the U.S. Atomic Energy commission's Oak Ridge, Tennessee facility. His responsibility there included analyzing the reactor component performance of the experimental molten salt reactor. From 1966-1968, he was General Manager of a Luxembourg company that designed and manufactured nuclear equipment. He worked on the design and mechanical testing of nuclear equipment in Grenoble, France for the French Atomic Energy Commission and for the U.S. Atomic Energy Commission at Oak Ridge before that.

Mr. Houtzeel earned his mechanical engineering degree at the Institute of Technology in Delft, the Netherlands and went on to study nuclear engineering at the Institut National ds Sciences et Techniques Nucleaires, Saclay, France. He also holds an MBA degree from the European Institute of Business Administration in Fontainebleau, France.

## ABSTRACT

The uses of classification and coding as a tool to integrate computer-aided design and manufacturing are described. The information revolution has created an enormity of data which is increasingly difficult to access. In recent years, companies have turned to classification and coding systems as a means of organizing raw data and retrieving useful relevant information. Essentially, classification is a means of separating raw information into classes of similar information; coding is a means of retrieving the information so that it can be analyzed and applied to accomplish specific objectives. The MULTICLASS system enables the user to employ multiple coding systems that can be used for various information retrieval and analysis purposes i.e., retrieval and standardization of manufacturing information, assembly information, tool retrieval, electronics, material selection and use.

## BACKGROUND

### Early Coding and Classification

Coding and classification systems have been used for many years - in libraries, for example, and in other information retrieval applications. Such systems were not widely used in the manufacturing industry, however, until after World War II.

In the late 1940's and early 1950's, systems were developed for the manufacturing industry. They were primarily intended for design retrieval.

They were highly customized code systems, utilizing five to eight digits to describe design attributes of machined and other parts.

The vendor/consultant would work with the potential user to determine types of classifications to be incorporated into the system, and the number of items per class. In actual practice, the user determined the the number of parts in each class, although the vendor/consultant might provide some guidance.

The vendor/consultant would then analyze the customer's part designs, going over several thousand to as many as ten thousand parts. The designs would then be arranged in groups, and the system would be built around these groups. It was usually a manual system, based on hierarchical principals. (See Figure 1.) In other words, the value of each digit depended on the value of the digit preceeding it. For example, the number five in the second position would have one meaning if the first position number indicated a turned part, and a totally different meaning if the first position digit indicated a box form (i.e. a different branch of the hierarchical tree).

This approach worked very well in the United States and Europe (including Eastern Europe) for design retrieval purposes. The Brisch - Birn System is a good example. Such systems did not normally accommodate manufacturing requirements, however.

### Application to Manufacturing

In the late 1950's and early 1960's, manufacturing oriented research was carried out in several European countries, including Germany, particularly at the University of Aachen. Researchers surveyed parts being made by the German machine tool industry.

It became evident that although the designs and functions might be different, there were many similarities in the parts being manufactured. This was not only true within individual companies, but also applied across the entire German machine tool industry.
This work led to the development of a classification and coding system for the manufacturing environment (The Opitz System). Within this system, parts which were manufactured in the same way were grouped together.

It should be noted that parts which shared common manufacturing approaches did not necessarily have the same design characteristics. Similar parts from a manufacturing point of view are often different than similar parts from a design point of view. (See Figure 2.)

The application of classification and coding established that large numbers of similar parts were being made over and over again by manufacturing organizations. If large numbers of similar parts were being manufactured almost continuously, then why not dedicate groups of machine tools to manufacture these parts? With such a scheme, common jigs, fixtures, and tools could be used. Set-up times would obviously be reduced, as would throughput times. This led to the development of Group Technology workcells. The machine tools in each workcell thus formed were often placed together. Machinists and foremen jointly shared the responsibility for making parts. (See Figure 3.) The early workcells resulted in a "poor man's mass production" - they created great improvements in productivity, and lowered throughput time, set-up time, and work-in-process costs.

The technique was applied in several plants in Europe and the United States with limited success. The problem was that it was primarily effective in relatively simple operations which did not have complex product mixes.

Many implementations were not successful. This was due to the fact that there were no analytical tools available to properly analyze the parts database for production flows, and to simulate load balances. A workcell might use one lathe 120% of the time, an adjacent milling machine only 10% of the time, and a grinder only 15% of the time. Balancing each workcell production load was an obvious problem.

In addition, there was great resistance to change on the part of managers. Managers did not like to rearrange tools, and wait one to two years for productivity increases to become apparent.

Thus, the workcell idea was restricted for the most part to plants with simple products.

Application to Design and Manufacturing

Through the 1950's and 1960's, there were coding and classification systems for design and coding and classification systems for manufacturing. They were primarily manual systems, using a relatively few number of digits or alphanumeric codes. None combined design and manufacturing applications.

Work at the Organization for Applied Scientific Research in The Netherlands (TNO) was carried out in the 1960's and 1970's to develop a classification and coding system which would serve both design and

manufacturing needs, This work led to the development of the MICLASS system which included both design and manufacturing oriented sections. To meet both types of requirements, however, a code length of as many as 30 digits was required. In the manual system environment which existed at that time, the 30 digit code length could have been a problem.

TNO's response was to develop a computerized system which handled the classification and coding process in an interactive mode. This was quite a new approach at the time. Computers in the manufacturing environment were mostly used in batch modes up until then.

MICLASS

With the MICLASS System, the computer would ask a number of questions about the part being coded. These questions would relate to both design and manufacturing attributes. The computer might ask, for example, if the piece were round. If the answer were yes, it might continue by asking if it had deviations. It would then continue until it had enough information to create the code number. The user was required to respond only with "yes", "no", or with dimensions. The code number was set up essentially as a chain in which individual part attributes were represented by code number digits, thus "chaining" the part attributes together. (See Figure 4.)

When the code number was created, the computer would search its files to determine whether a part with the same or similar attributes had been designed or manufactured in the past. The code number thus became much more than a notation on a drawing: it was now the key to a database; a tool to recall what had been done in the past.

MICLASS also departed from previous systems by providing a universal code. A MICLASS code number could be as much as thirty digits long. The first twelve digits, which related to shape, form, dimensions, tolerances, and materials, were kept standard for all users.

There was initial resistance to this concept. It disturbed manufacturing people who were convinced that their parts were different from all others, and thus required a specific coding system. The fact remained, however, that all of these manufacturers were using the same standard machine tools to produce these highly similar parts, and the differences were not profound. Furthermore, the availability of eighteen additional digits meant that each user's MICLASS System could be customized to meet specific needs. It was thus possible within a corporation, for example, to have a basic twelve digit code which would serve the entire corporation, while each division had additional digits of its own to reflect specific needs. MICLASS thus provided both customized coding and classification, and *a* universal key to the database.

The MICLASS coding structure was based on TNO's analysis of many thousands of parts. From this analysis, family concepts had been developed. Thus, the vendor/consultant no longer asked the user how to structure the families; the structure was provided. If there were too many parts in a given class, it was a strong sign of unneccesary duplication.

Within this concept, MICLASS provided a tool for standardization.

If a user found that there were a number of allegedly different parts or process plans with the same code number, there had to be duplication. For example, a machine tool builder was found to have 521 similar gears. The files revealed 477 different process plans to produce these gears. When MICLASS coding focused attention on this situation, it was possible to reduce the 477 process plans to 71 standard "best" plans, thereby greatly simplifying production.

The MICLASS Matrix

The MICLASS System included a thirty position code. Values ranging from zero to nine could be assigned to each position. Therefore, MICLASS incorporated a 30 x 10 matrix - 300 places. When parts were being coded, they fell through this 300 hole "sieve". (See Figure 5 .) The proper definition of the eighteen "non-universal" digits in the MICLASS code became critical to the success of its application in any given organization.

OIR - The Organization for Industrial Research, Inc. - implemented MICLASS in many American companies in the late 1970's. Through these implementations, OIR developed a great deal of experience in the assignment of these digits in ways which were most beneficial to the user.

Both hardware and software technology moved rapidly in the late 1970's. Computers became smaller, cheaper, more powerful, and more frequently used as an interactive tool. The number of computers in manufacturing organizations grew significantly. Interactive coding and classification thus became very attractive. It provided the key to an interactive, intelligent interface between the users -- design and manufacturing engineers -- and the parts database.

## Problems of Integration

As the use of computers in manufacturing grew, and as computer-aided design and computer-aided manufacturing became more widely accepted, new types of problems began to emerge.

It as not unusual for the design office to use a computer, and the manufacturing office to use another computer. Even if they were using the same machine, they often worked from different databases. At the same time, there might be a corporate database with information of use to both design and manufacturing, if it could be retrieved. There were growing pressures for the true integration of CAD and CAM.

The problem appeared to be in the quantities of data involved. A company might have hundreds of thousands, or even millions of parts. The integration of all the data for all parts would appear to be a monumental problem.

The key to the solution of this problem was the fact that things were not as they appeared to be.

In its work for many different companies, OIR had found that the number of truly different designs in any manufacturing environment range from approximately 2,000 to 6,000. Even companies with 500,000 parts or more prove to have no more than 6,000 really different designs or process plans. Thus, if the database could be sifted to find the few thousand really different parts, the problem would be much reduced.

As described previously, the early applications of classification and coding were in the design area, for design retrieval purposes. With the development of MICLASS, the applications were extended into manufacturing. Through the use of Group Technology analyses, design and manufacturing databases could be reduced to manageable size, The key tool in such an effort was OIR's MIGROUP family of programs which made it possible to thoroughly analyze and act on databases of part information in three basic areas: code number analysis; production flow analysis; and machine load analysis. Coding and classification became the 'sieve' to reduce the database size, and Group Technology was the tool for design and manufacturing analysis.

## Computer Assisted Process Planning

In the 1970's CAM-I (Computer Assisted Manufacturing-International) looked at the feasibility of computer assisted process planning. At the time, computers were being used in process planning, but not at all effectively. In some companies, process plans were written out by hand, then sent to a key-punch operation and read into the computer., The computer would then produce a printout of the process plan as it had been key punched. In other words, the computer was serving as a multi-million dollar printing press.

The issue was how to consistently find and retrieve best process plans. The use of a part number had limited value. The number says nothing about how the part is to be manufactured, and part numbers are easily lost, confused, or forgotten. It seemed obvious that a code number would be more useful.

In 1979, OIR introduced MIPLAN, the world's first commercially available production oriented computer assisted process planning system.

## The First Generation

With the development of MIPLAN, the first generation of classification and coding/Group Technology tools was complete. The MICLASS classification and coding system captured both design and manufacturing information, MIGROUP provided a means of analyzing and integrating such data, and MIPLAN was a practical means of applying computerization to process planning. (See Figure 6.)

With these tools in place it became possible to realize benefits which had not been possible only a few years before.

For example, MIGROUP analysis solved the problem of creating effective workcells in complex manufacturing environments. By coding parts and then analyzing them with MIGROUP, it was possible to define part families, production flow (what parts to what tools), and through simulation, to achieve load balancing.

In addition, OIR's increasing experience made new insights possible. For example, OIR found that even though product models may change, frequencies within part mixes remain relatively constant from year to year -- the number of truly different parts changes very little. This made it possible to form groups of dedicated machine tools for particular part families to serve both short and long term needs. Furthermore, it became clear that, it was not necessary to physically group the dedicated machine tools together, only to assign them to part families.

With the application of MIPLAN, it became evident that computer assisted process planning was useful not only for retrieving process plans, but that it could also be used for cost reduction. A small shaft, for example, could be made on a small lathe, or a five axis milling machine, with obvious manufacturing cost differences.

It became apparent that process planning was a major determinant of the final cost of a product. Hence, the optimization of process planning would translate into optimal product costs. MIPLAN provided a tool to serve this purpose.

The database of code numbers, with their associated process plans, served as a "back door entry" into Group Technology analysis. As this database of manufacturing information, organized by code numbers, was built up, it would become possible to move in the direction of standardization using Group Technology, by analyzing the code numbers.

In other words, planners would begin by using the system as an "electronic pencil", and utilizing the time they saved in using the system, they could begin to standardize process plans, and define optimal manufacturing methods.

## Pictorial Process Planning

In the 1970's, there was a tremendous growth in the acceptance of computer graphics systems.

We are in the age of visual communications. Spurred on by television, we are in a period when people are reading less and less and relying more on pictures and illustrations than ever before.

Process plans can be very lengthy documents to read - in some companies they normally run twenty pages or more. With people reading less and less, and with increasingly poor comprehension levels, the integration of computer assisted process planning and computer graphics presented an interesting opportunity.

OIR developed a pictorial process planning system (initially with Computervision) that merged the benefits of both these technologies.

With pictorial process planning, the user utilizes an alphanumeric terminal to compose the process plan, and a graphic terminal to illustrate the plan with machining details, tool set-ups, etc.. A formatter is used to join them, and hard copies with the process plan on one-half of the page and the accompanying illustrations on the other half of the page are now practical. The results are dramatically clear process plans. (See Figure 7.)

At the moment, the use of pictorial process planning is limited because of the capacity of existing graphic systems.

With the introduction of new 32 bit graphic systems, however, the alphanumerical and graphic terminals will be jointly used in the process planning environment, with more users on each system.

## THE FUTURE -- THE TECHNOLOGY OF THE EIGHTIES

Classification and coding, Group Technology, and computer assisted process planning are now entering into a new phase in their evolution - a phase which reflects the advancement of hardware and software technology, the increasing sophistication of manufacturing people, and the rising economic pressures on manufacturing organizations.

## MULTICLASS

The first of the new generation of classification and coding systems is MULTICLASS, developed entirely by OIR.

The development of MULTICLASS began with a detailed analysis of years of experience with the MICLASS System. The analysis revealed that the 30 x 10 matrix of the fixed MICLASS structure was not always the most efficient approach to classification and coding. In fact, each user tended to take advantage of only a portion of the matrix, depending on individual needs.

In fact, if the matrix was looked on as a 30 x 10 sieve through which the parts passed as they were classified, an individual company's use of the sieve might be graphically depicted as a potato shape. (See Figure 8). The shape of the potato varied with each company, but was similar for companies in the same type of industry.

In almost all cases, the size of the potato actually used was small. In other words, the typical user took advantage of only a small section of the matrix, and much of the use involved sections of the code which were specially tailored for the user company.

It should be noted that the issue is not just in the number of digits per se. The coding process is essentially a decision tree process. Coding with an entire tree when only a small branch is needed means that extra time, energy, and computer power is wasted.

At the same time, the success of classification and coding and computer assisted process planning for machine parts and sheet metal parts had encouraged manufacturers to seek to apply the same techniques to other types of components - machine tools, assemblies, electronics, etc..

The MULTICLASS concept responds to both these situations.

MULTICLASS is a comprehensive software system which can handle multiple coding structures. Instead of a fixed format, such as MICLASS, MULTICLASS is a very flexible tool which can be tailored to meet the user's specific requirements. MULTICLASS can be used vertically, for increasingly specific classification, and horizontally, to accommodate different types of components (machined parts, electronics, etc.). See Figure 9.

For example, a thirty-two digit code structure can be used in MULTICLASS to organize a total database into generalized families for sheet metal and/or machined parts. With the new MULTIGROUP analysis system, it is then possible to analyze these families and create individualized decision trees for them, thus creating a more finely tuned system which meets company needs extremely efficiently.

The process can be repeated to create an even more finely tuned system, using the decision tree "handlers" in the MULTICLASS System.

Ultimately, the very finely tuned decision trees can be used with the MULTIPLAN computer assisted process planning system in a quasi-generative process planning mode -- where very specific process plans can be retrieved because the system is so finely tuned to the products being manufactured.

## Multiple Coding and Classification

The flexibility of the MULTICLASS System is demonstrated in its capability to handle almost any type of part or component used in manufacturing. In addition to machined and sheet metal parts, for

example, MULTICLASS can be set-up for the coding and classification of electronics, purchased parts, assemblies and sub-assemblies, machine tools and other elements.

MULTICLASS uses span the range of applications which have evolved in recent years and which will continue to evolve through the eighties, from simple design retrieval, to design and manufacturing standardization, to generative process planning.

MULTICLASS provides a common link for many different elements of the design and manufacturing database. Thus it is possible, through MULTICLASS, to meet all coding and classification needs (i.e. database interfaces) with a single system.

Therefore, the MULTICLASS System thus provides a common link for many different elements of the design and manufacturing database.

MULTICLASS is normally provided to the user with at least two general coding structures already installed -- for machined parts and for sheet metal parts. OIR specialists can then work with the user to define the other decision trees (if any) which will be needed initially. In time, the user will add other structures to meet specific needs as they evolve. In practice, the user has the opportunity to analyze his needs using the general coding structures and then design the more specific decision tree structures. It is much like having a large funnel and then using smaller funnels to catch more specific attributes.

This is in contrast to the decision tree system developed at Brigham Young University. DClass, as it is called, is a very capable decision tree handling system. It is not marketed with any specific coding structures already set-up, or with any group technology analysis programs. Thus, the user has to "start from scratch" and do the most difficult work himself.

MULTIPLAN

The MULTIPLAN Computer Assisted Process Planning System also goes well beyond anything which was previously avalable.

MULTIPLAN has the MULTICLASS System embedded in it. This means that the user has a wide range of options in using it. Again, the options are both verticai and horizontal.

The vertical flexibility of MULTIPLAN means that it can be utilized as a generative process planning system as well as being used as a variant system. Because the MULTICLASS structure makes it possible to code with increasing sensitivity to any type of specific attributes, it is possible to begin with a general structure for variant planning and then, with use, to become increasingly specific.

MULTIPLAN can thus be used progressively -- from an "electronic pencil," to a variant system, to generative process planning. The advantage for the user is that the return on investment begins almost immediately

MULTIPLAN has also been designed for horizontal use. In many manufacturing operations today, the components involved in production are not limited to machined parts or sheet metal. There may be electronic components, electro-mechanical devices, assemblies and sub-assemblies, purchased parts and more. The MULTIPLAN System will accommodate whatever components are manufactured or assembled. Again, a major advantage is that all of this is done within a single system.

MULTIGROUP

The MULTIGROUP System represents a quantum jump in Group Technology. Its development also resulted from a detailed analysis of years of experience in actual Group Technology applications.

It thus reflects both the experience of the past decade and the technology of the next. Whereas past Group Technology systems, including MIGROUP, were somewhat cumbersome and required a great deal of technical knowledge to operate successfully, MULTIGROUP is a menu-driven, clearly articulated system that can be introduced and applied much more quickly and efficiently than systems of the past generation.

MULTIGROUP can be used to analyze product mix, workload, and work center activities, in addition to its application to the formation and analysis of part clusters for such things as part family definition and generative process planning.

In brief, MULTIGROUP is a very modern tool for design and manufacturing standardization, the development of optimal routings, purchasing decisions and much more. In many ways, it is the realization of the initial promise of Group Technology "to bring the economies of mass production to batch manufacturing."

MULTIGROUP is the first Group Technology system to incorporate a flexible database approach. Like MULTICLASS and MULTIPLAN, its applications can extend far beyond machined and sheet metal parts -- to electronics, assemblies, and all of the other types of components used in contemporary manufacturing environments. It can work with different numeric codes or designators, and with the full range of MULTICLASS decision trees. It can thus be used to analyze the production of a very large plant or company, or to balance the load in a very small workcell.

MULTIGROUP greatly expands the practical applications of Group Technology and, in many ways, is the realization of the potential which Group Technology exponents predicted.

## Transition From MICLASS

One of the problems associated with the introduction of new software systems has been incompatibility. A new system is developed and the old system must be completely abandoned. This is not the case with the transition from MICLASS to MULTICLASS.

The MULTICLASS System can contain a MICLASS module which may be accessed directly, and it is possible to use MICLASS as the first step in the development of highly specific machined and sheet metal part MULTICLASS codes. It is also possible to re-code MICLASS coded parts into MULTICLASS.

It should be noted, however, that the much broader 'scope and greater depth of the MULTICLASS System would make it advisable for new Group Technology users to begin with MULTICLASS. There is no reason to include MICLASS in a new system.

## Generative Process Planning

"Generative" process planning has been a subject of increasing discussion in recent years. In a generative process planning system, process plans are generated automatically -- that is, the user enters a description of the part, and the system automatically generates the correct process plan to produce it. The term "generative" is usually used in contrast to "variant." In a variant system, the user enters a description or identification of the part and the system produces a process plan which may require editing or assembly before it can go out on the shop floor.

There are essentially two approaches to generative process planning. The first incorporates theories of artificial intelligence. In such a system, the geometry of the part is recognized and the system generates the plan based on its understanding of the manufacturing methods needed to produce such a geometry.

In the other approach, Group Technology is the key. Here, the process plan is based on the prior determination, through Group Technology analysis and classification and coding, of the "best manufacturing" methods for the part at that production facility. Past experience, available machine tools, families of parts, and other considerations come into play.

The major advantage of the Group Technology approach is that it can be built up over time, while the user is deriving benefits from the process planning system. With the MULTIPLAN computer assisted process planning system, for example, the user can begin by utilizing the system as an "electronic pencil" to significantly reduce process planning time. As the system is used, a database is being built for standardization of design and manufacturing, selection of optimal manufacturing routings, definition of highly similar parts, and other factors required for the implementation of generative process planning.

The resulting system is thus much more finely tuned to the user's needs and has produced a return on investment prior to the full-scale implementation. It has also been tested in use as it is being developed.

The OIR approach is thus directed to Group Technology.

## The Future

Classification and Coding, Group Technology, and Computer Assisted Process Planning have progressed rapidly in the past few years, evolving from novelties to widely used working tools. In the process, many production economies have been achieved, and the productivity of the people involved has increased measurably as the need for human intervention for repetitive work has become minimized.

Although hardware and software technology has improved tremendously in recent years, Computer Aided Design and Computer Aided Manufacturing are still in their infancies in many ways.

In the future, computers will begin to really understand what is in their databases, using solid modeling technology. Decision trees embedded into computer graphics systems will generate process plans virtually automatically, by truly recognizing parts and other components. It may be at that time that code numbers are no longer needed, since retrieval and analysis will be direct and automatic. The new OIR systems provide a base for such technology.

The disappearance of code numbers would mean the end of human involvement in such things as the preparation of process plans. While this may become technically feasible, there are serious questions as to whether it would be desirable.

The computer is a very useful tool and it should be used to maximum advantage. On the other hand, manufacturing is -- and will be -- both an art and a science. Human judgement is an essential element of the manufacturing process. As systems evolve, there will still be a need for judgements by design and manufacturing engineers, process planners, and others.

Without such judgement, we could make a goat when we are looking to produce a camel.

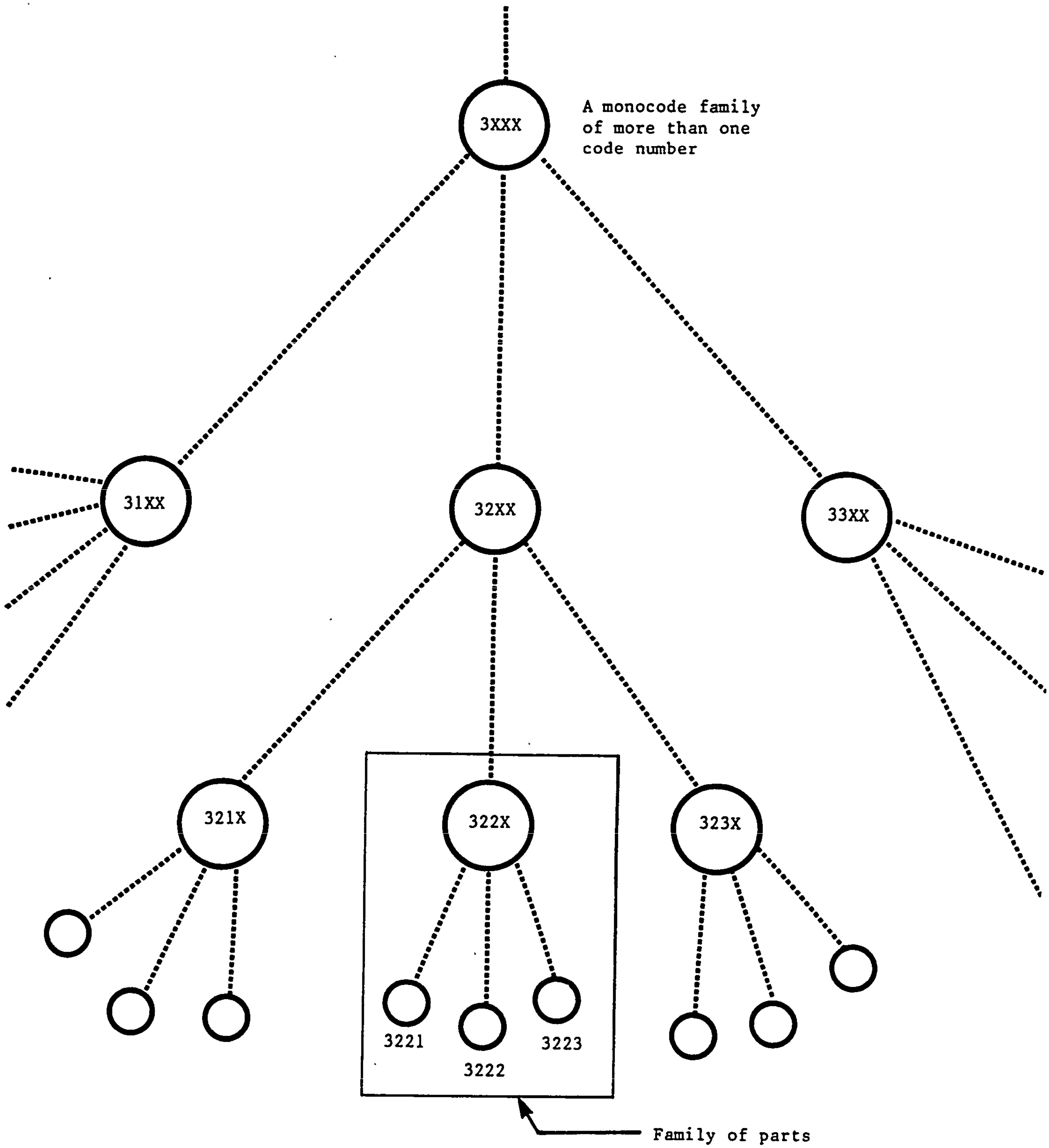


*FIGURE 1*

*The Structure of a
Classification and Coding System
Based on Hierarchical Principles*

# Similar Parts Based on Manufacturing Process

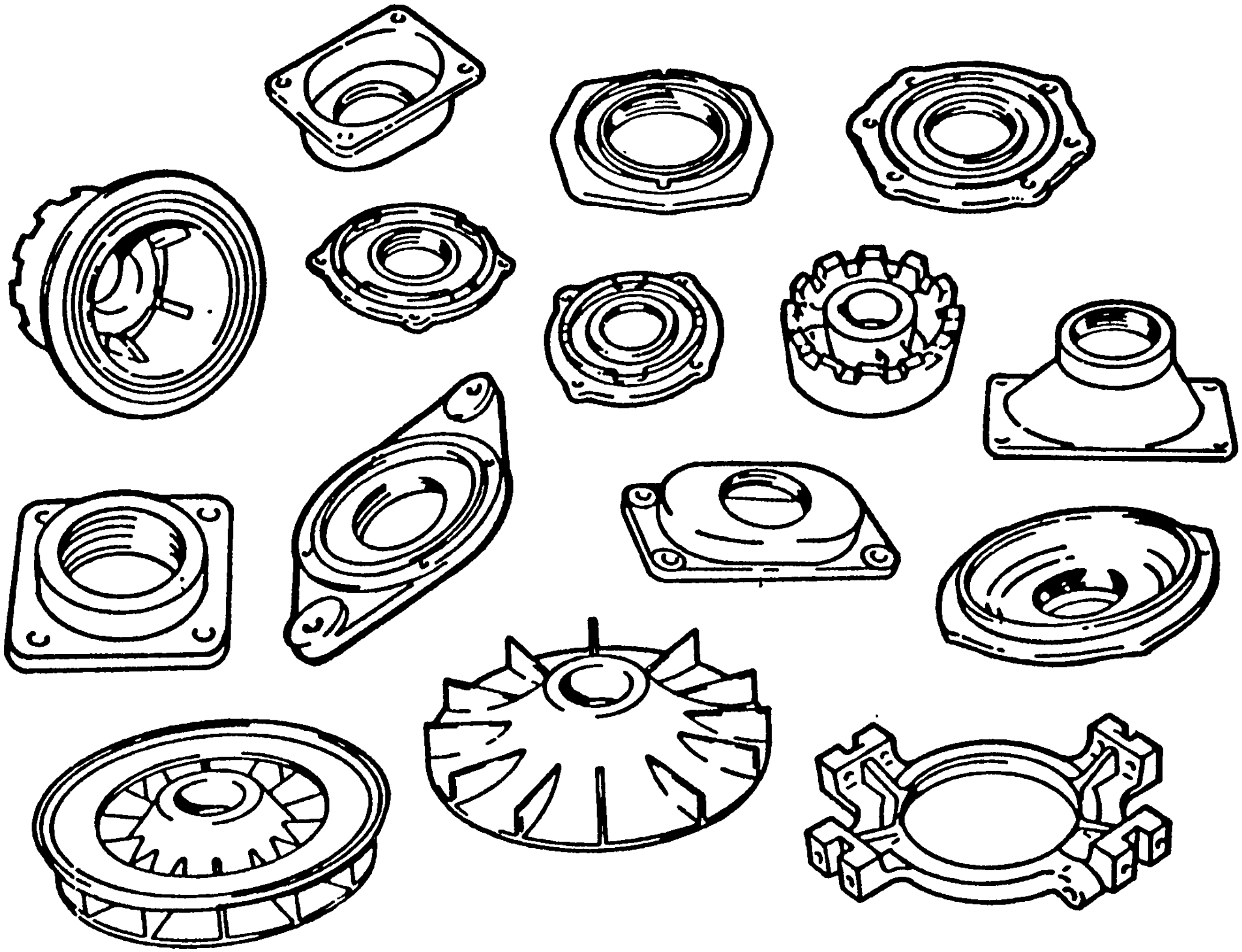

*FIGURE 2A*

# Similar Parts Based on Shape

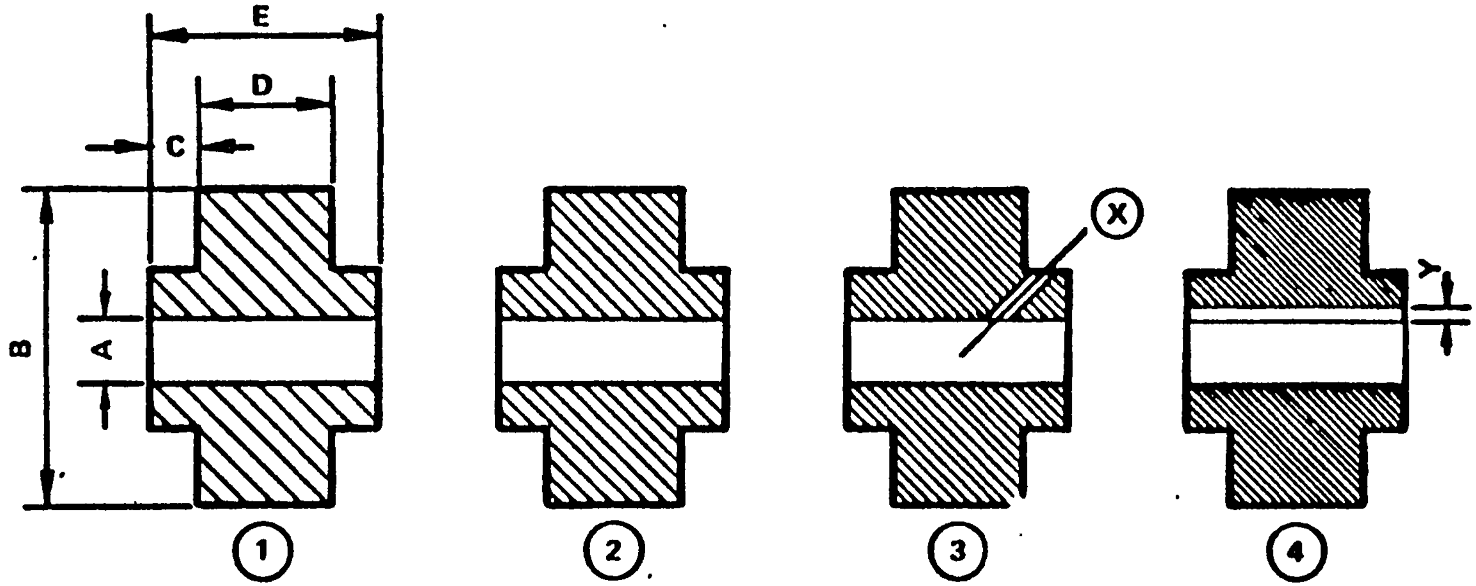


FIGURE 2B

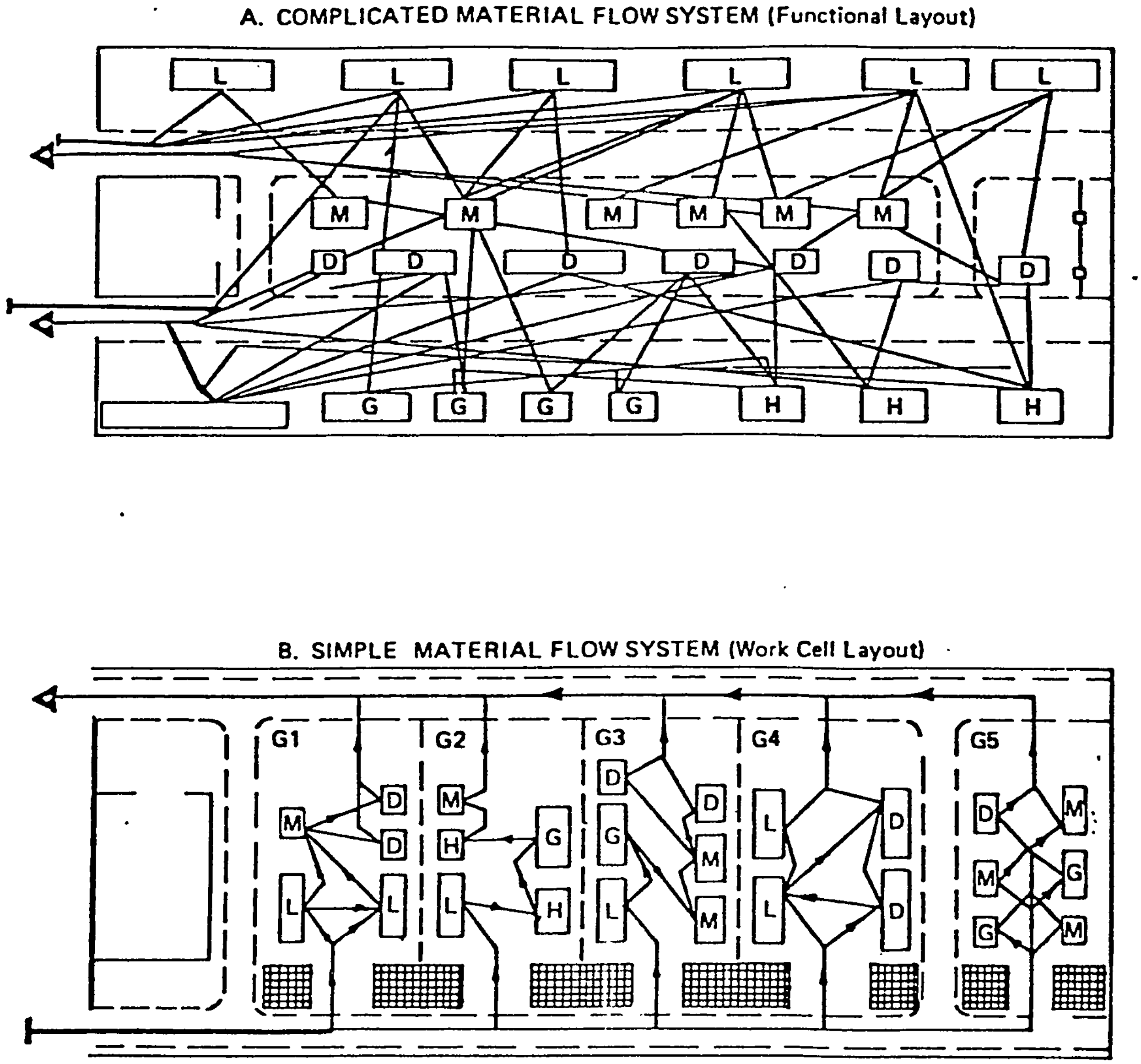


*FIGURE 3*

*Simplification of Material Flow*
*With Work Cell Layout*

## POLYCODE STRUCTURE

| DIGIT | CLASS OF FEATURE | POSSIBLE VALUES OF DIGITS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | EXT. SHAPE | $SHAPE_1$ | $SHAPE_2$ | $SHAPE_3$ | – | – | – | – | – |
| 2 | INT. SHAPE | NONE | $SHAPE_1$ | – | – | – | – | – | |
| 3 | # HOLES | 0 | 1 – 2 | 3 – 5 | 5 – 8 | | | | |
| 4 | TYPE HOLES | AXIAL | CROSS | AXIAL & CROSS | | | | | |
| 5 | FLATS | EXT. | INT. | BOTH | | | | | |
| 6 | GEAR TEETH | SPUR | HELICAL | | | | | | |
| 7 | SPLINES | | | | | | | | |

*FIGURE 4*

*A Classification and Coding System Based on Polycode Structure*

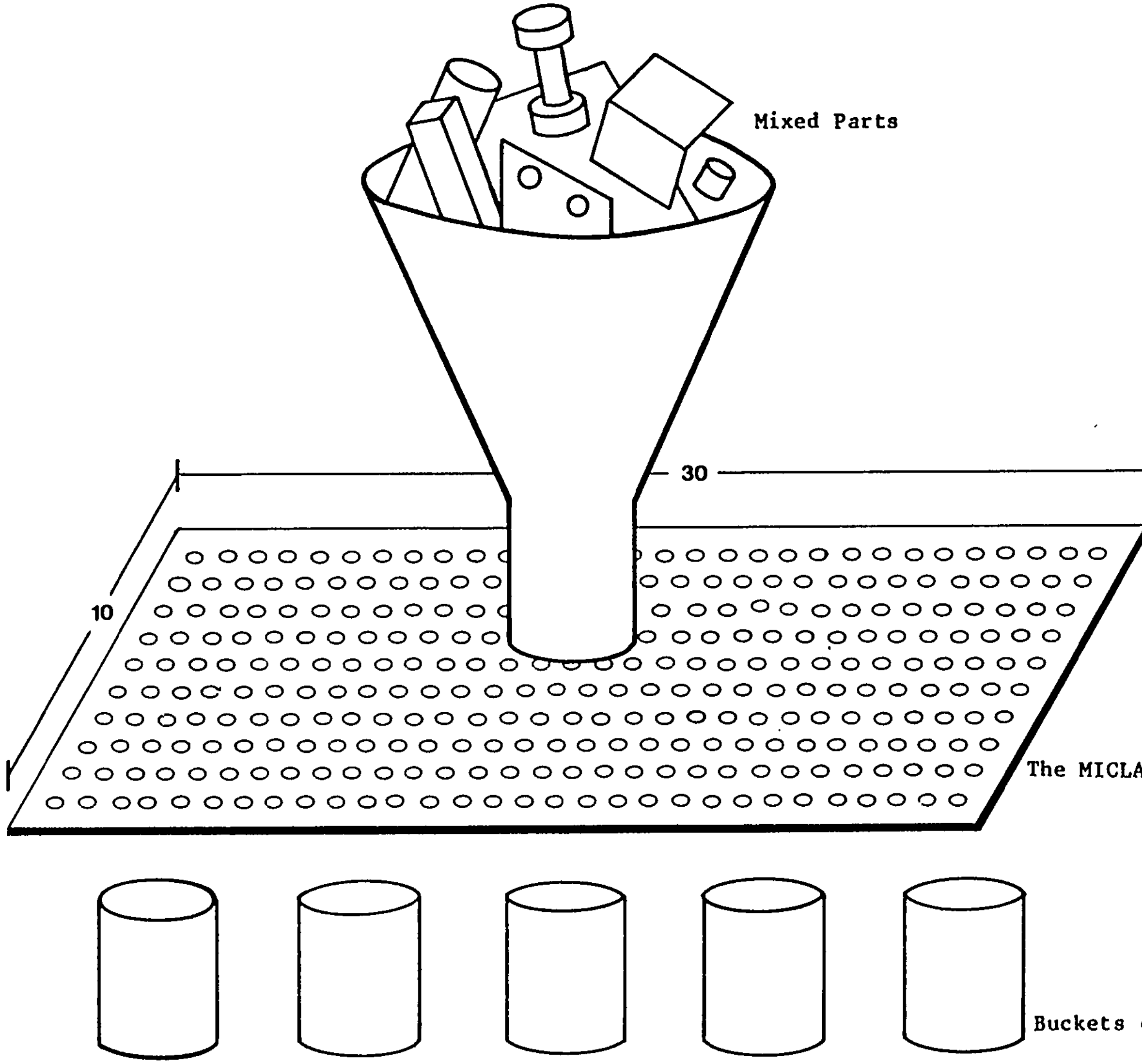


*FIGURE 5*

*A Classification and coding system can be compared to a sieve which sorts parts by specific attributes. The MICLASS System works like a sieve with 300 holes.*

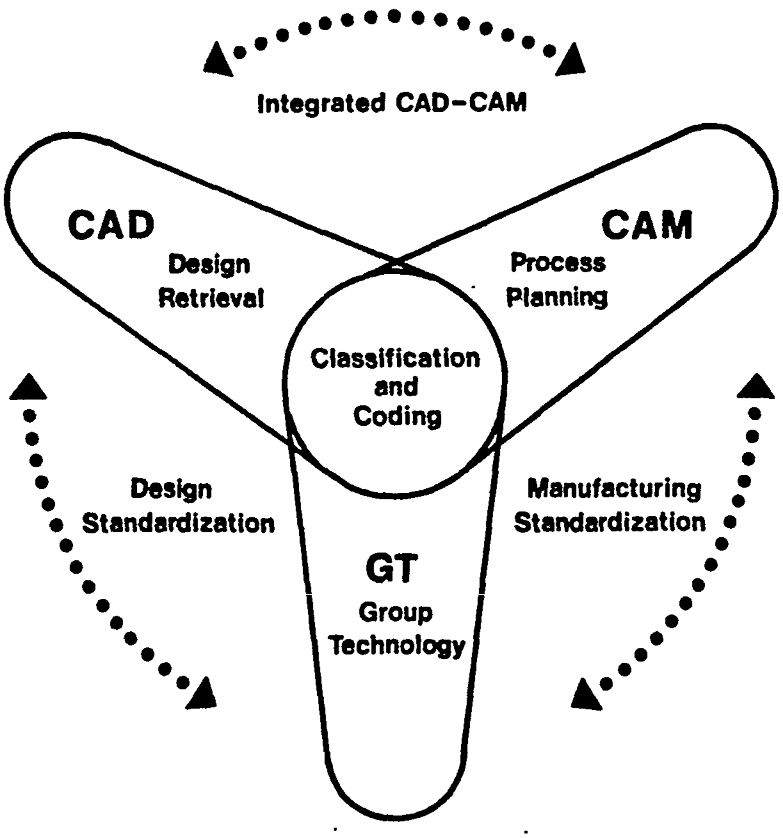


*FIGURE 6*

*Classification and coding is the key to an integrated approach to CAD and CAM*

| | |
|---|---|
| PART NO: 190105 PART NAME: FRONT PLATE FORMAT: NCS.1 | |
| PLNG REV: 1 DWG REV: A PLANNER: ADAMS | |
| CODE # 8798-3711-1189-3433-1400-0000-0000-00 | |
| 0040 | 5002 MACHINE PER TAPE #1 |
| | SET UP IN FIXTURE #1 |
| | WITH STD ANGLE PLATE |
| | #A123 PER SKETCH |
| | ROUGH & FINISH FACE |
| | - HOLD .25+-.02 DIM. |
| | USE 4" DIA FACE MILL |
| | C-DRILL (3) HOLES |
| | DRILL (1) HOLE 3/8 DIA. |
| | DRILL (2) TOOLING HOLES |
| | 5/16 DIA. |
| | DRILL (2) TOOLING HOLES |
| | .365/.370 DIA |
| | AND REAM TO .376/.370 DIA. |
| | SET UP = 2.50 |
| | PIECE TIME=.350 |

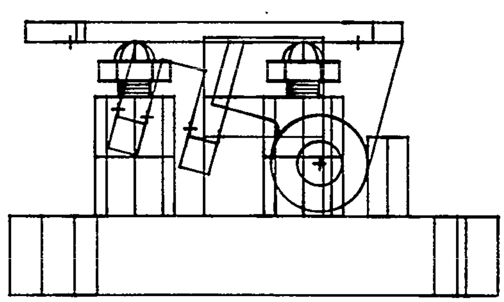

*FIGURE 7*

*Pictorial Process Planning*
*is the Integration of*
*Computer Assisted Process Planning*
*and Computer Graphics*
*Shown above is a sample print out.*

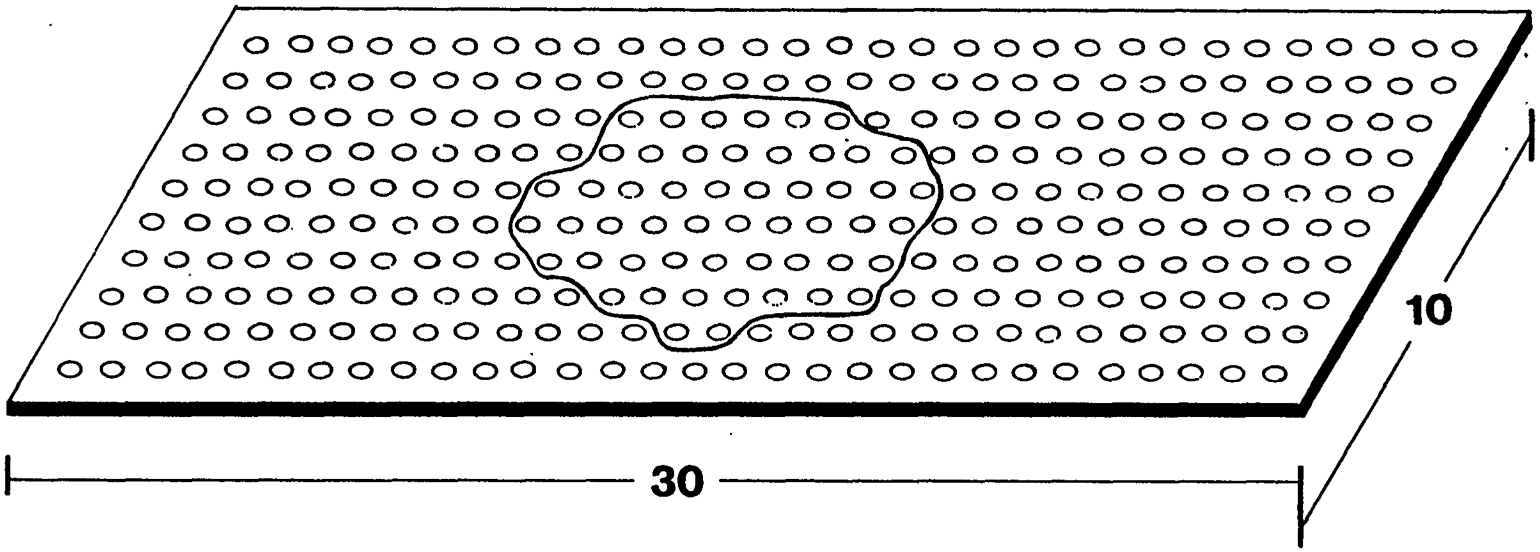


*FIGURE 8*

*A fixed classification and coding system is not always the most efficient. The "potato shape" represents the relatively small portion of the MICLASS matrix typically utilized by a company.*

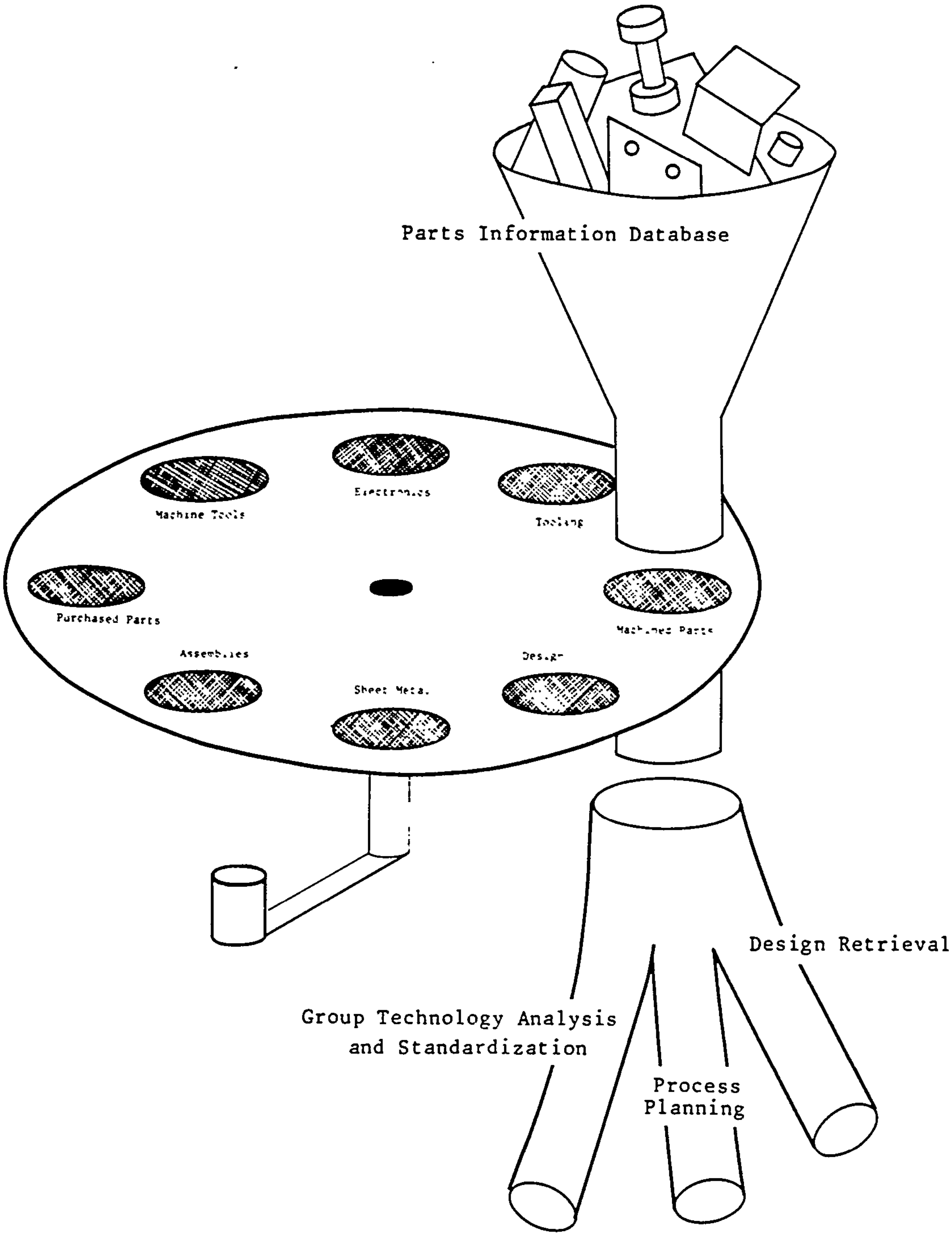


*FIGURE 9*

*In contrast to the "fixed sieve" metaphore for MICLASS, MULTICLASS can be likened to a machine that offers a wide selection of different sieves. That is, MULTICLASS is a very flexible tool which can handle multiple coding structures and can be easily tailored to meet a user's requirements.*

# WELD ACCEPTANCE STANDARDS

Bruno L. Alia
Chief Surveyor
American Bureau of Shipping
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Mr. Alia began his career at the New York Naval Shipyard in 1955. He completed a 4-year apprenticeship program as a combination welder and worked as a journeyman welder, shop planner, and nondestructive testing technician in connection with construction of naval combatant ships. From 1956 to 1958, he served with the U.S. Army in Germany. In 1963, he joined the U.S. Naval Science Laboratory and was engaged in welding process development in connection with Navy deep submergence programs. In 1967, he joined the American Bureau of Shipping as a surveyor. In his present position with this international company, he is Head of Materials Engineering, Containers, and Quality Assurance Departments and is responsible for material selection, welding, fabrication and nondestructive testing in connection with ships, drilling rigs, offshore structures and other marine structures, administering quality assurance programs, and certification of ship containers. He has performed metallurgical consultant work for the ABS Group of Companies. Mr. Alia is the ABS representative on numerous AWS Committees including Chairman of the Welding in Marine Construction Committee. U.S. Representative on IIW - Commissions IX and X, a member of SNAME Ship Production Committee on Welding, and a member of ASME Subcommittee on Welding.

Mr. Alia graduated from Cooper Union for The Advancement of Science and Art, with a BS degree in mechanical engineering and is a member of Pi Tau Sigma and Tau Beta Pi.

Irving L. Stern
Assistant Chief Surveyor
American Bureau of Shipping
New York, New York

Mr. Stern, has been employed as a Materials Engineer and Welding Engineer at the Brooklyn Navy Yard and served as Head Welding Section and Fabrication Program Manager. In the course of these duties he received the Navy Meritorious Civilian Service Award for his efforts in Steel Fabrication Development. In 1970, he joined the American Bureau of Shipping, and is currently Head of the Materials Engineering Section, which is responsible for material, welding, fabrication and nondestructive testing. He has written and presented numerous technical papers on materials, welding and nondestructive testing, among which is the Chapter on Hull Materials and Welding in the SNAME publication Ship Design and Construction.

Mr. Stern has a BS degree (C.C.N.Y.), M. Met Engr (Polytechnic Institute of Brooklyn) and is a licensed Professional Engineer (N.Y.).

## ABSTRACT

The presentation will cover the objectives and summarize the progress of MARAD SP-7 Panel programs on (a) development of reference standards for visual inspection welds, and (b) evaluation of the quality of existing ship welds by ultrasonics. The relationship of the visual acceptance standards; quality control procedures, quality of production welds and the significance of representing acceptance standards with model reference standards will be discussed.

Ultrasonic evaluation of the quality of existing ship welds will be related to the existing radiographic and ultrasonic examination' conducted outside areas required by the governing code or rules. This may occur in new construction or after various periods of service. Unnecessary repairs can be costly and at times can degrade rather than improve structural reliability; on the other hand, internal discontinuities that represent a significant degradation of structure should be repaired. The ultrasonic evaluation program will be related to the above as well as to the ABS guidelines to cover analogous cases.

This paper will describe two investigations conducted by ABS which were supported under MarAD auspices via the SNAME SP-7 Committee. One investigation was concerned with the radiographic and the ultrasonic examination of ship welds between intersections; the other with visual reference standards for weld surface examination. Both are directed toward areas where the weld acceptance standards are somewhat vague or non-existent and a source of confusion to inspectors and surveyors. In cases where acceptance criteria are not specific, controversy is encountered where the various parties concerned have differences of opinion as to the acceptability of a weld.

To approach the first problem, which is concerned with nondestructive inspection (NDT). of welds for internal soundness, we must understand the basis of our present requirements. In 1963 the AHS Rules only indicated that welds be inspected in important locations by an established radiographic technique. To develop a more specific requirement, a worldwide survey was conducted and various questions were asked of shipyards as to details of their inspection methods, their techniques and their acceptance standards. A proposed standard was offered for their consideration and comment. Results indicated that there was extensive use of NDT in shipyards, primarily x-ray and isotopes, and in a few cases ultrasonics. Standards used were ASME, Navy, IIW, JIS and some internal standards. Based on the results of the survey and the comments of the **shipyards,** the ABS "Guide for Radiographic Inspection of Hull Welds" was issued in 1965. The Guide specified where radiography should be conducted and the acceptance standards which would be applicable. In September 1971, the Guide was modified and reissued as "Requirements for Radiographic Inspection of Hull Welds".

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In 1969, ABS initiated the development of requirements for ultrasonic inspection which followed the same route as with radiography, i.e. looking at what is available, getting comments from the shipyards, and proposing standards. In 1972, ABS issued "Provisional Requirements for Ultrasonic Inspection of Hull Welds". After these were in use for several years, modifications were made based on industry comments, and the ABS "Rules for Nondestructive Inspection of Hull Welds" was promulgated in 1975 which included both radiography and ultrasonic inspection. These Rules indicate the extent of inspection, location of inspection and acceptance standards. Location is primarily midship, with random inspection being conducted outside the midship area. Within the midship, radiography or ultrasonics is specified to be conducted at "intersections of butts and seams in the shear strakes, bilge strakes, deck stringer and keel plates, and butts in and about hatch corners in main decks and in the vicinity of breaks in the superstructure". There are no speific requirements to perform radiography or ultrasonics between intersections. The problem we are addressing is that at times some additional radiography or ultrasonic inspection is conducted between intersections either at an owner's request or in connection with a shipyard's or other organizations initiative in checking welds. Since there are no specific acceptance standards, questions as to what is acceptable and what is not acceptable become a source of controversy, and in many cases unnecessary repairs are made because of the lack of definition of what is an acceptable or nonacceptable weld.

Possible solutions are to use the existing ABS Class A and Class B acceptance standards and apply them indiscriminately to all areas within the midship and outside midship locations respectively. However, to do this would mean that the shipyard was guaranteeing that all welds would meet such standards and

this would require 100% inspection of all its welds as is the general practice in the Boiler and Pressure Vessel industry. Service experience with ships indicates that this extensive inspection is unnecessary and uneconomical. on the other hand, to allow appropriate deviation from ABS Class A and Class B acceptance standards would require the development of a liberalized standard. This could be based on fitness for purpose in accordance with fracture mechanics concepts or service experience. The fitness for purpose concept has been ruled out because it requires consideration of too many factors which could not be taken into account for each individual weld due to shipyard and owner requirements that prompt decisions be made regarding acceptability of a particular weld. Service experience seems to be the logical approach. For this, we need information as to weld quality that has proven satisfactory in service.

A project of the MarAd/SP-7 Panel is to examine the welds between intersections in classed ships and *to* determine what has proven satisfactory in service. A problem encountered was the availability of ships; we found that there were not many ships that would be available. In general, organizations did not want their ships examined in areas where no inspection requirement existed. Fortunately, we did have a solution. The MarAd Ready Reserve Fleet was made available for inspection and a tentative acceptance standard that ABS has issued as a Guideline was used to evaluate the quality of welds in these ships. Our survey was conducted exclusively on deck welds, primarily at the 0.6L midship area, with 70% of our inspection carried out in this area. We did a proportionally higher than normal amount of inspection outside midship, namely 30%, because we expected that, if we were going to find welds that were of lesser quality, they could very well be outside the midships area. Ultrasonic examination was employed and we followed standard ABS procedures and used shipyard personnel, (Newport News personnel) to do the actual inspection. The reason

for selecting deck welds for examination was accessibility. Two acceptance levels were used as a basis for weld evaluation. (See Table A). One was the ABS Class A and B standards as specified in the ABS "Rules for Nondestructive Inspection of Hull Welds". The other was an ABS in-house Guideline that has been used in specific cases where the ship owner or ship designer and the shipyard do not have a meeting of minds as to the appropriate weld quality for random inspection. The ABS Guideline indicates that for butts between intersections in the midship areas, twice the ABS Class A acceptance criteria would be reasonable basis for acceptance and twice Class B for all seams between intersections and butts between intersections outside midship length. It was considered that for relatively unimportant areas for which less than twice Class B criteria could be tolerated, such areas should not be considered for evaluation by either radiography or ultrasonic inspection.

The survey consisted of 18 ships - containships, freighters, tankers and transports in the 400 to 600 ft. range which were built between 1943 to 1973. (See Table B). An average of 15 inspection locations for each ship were examined and each inspection consisted of a check point 24 in. long. These were the ships that were available; given a choice we would have included a few ships of more recent vintage. What is most surprising is the fact that comparatively few defects were found. Cut of the total 18 ships surveyed, only 7 ships showed any recordable indications for the locations inspected. For 11 of the ships, all of the inspected locations were sound and free of any significant ultrasonic indication. Of the 7 ships in which indications were found no conclusion could be drawn about the relationship between quality level and era of build.

Welds between intersections were evaluated with the standards that were previously mentioned, that is, either following the ABS Rules (Class A or B) or the ABS Guideline where we would apply twice Class A and twice Class B acceptance criteria.

The following results were obtained: Of the 195 midship inspection check points, 14 check points (7.2%) would not pass if the ABS Class A acceptance criteria was applied. Applying the more liberal guideline twice Class A for butts and twice Class B for seams, 11 check points (5.6%) would not meet the guideline. Of the 84 check points tested outside midship, 5 check points (6.0%) failed to meet the ABS Class B Rule Requirement and 4 check points (4.8%) failed to meet the more liberal guideline of twice Class B. There wasn't much difference between rejection under the ABS Rules or the more liberalized ABS Guideline acceptance standards - 19 rejections or (6.8%) versus 15 rejections or (5.3%). A summary of results is given in Table C. This trend was observed both within the midship and outside the midship area and applied to the length of discontinuity as well as the number of check points. For one ship we found the non-acceptance on the basis of ABS Rules was 6 check points (33.3%) as compared to 4 check points (22.2%). The overall quality of the ships examined was surprisingly good. Some significance may be attributed to the fact that only deck welds were examined and these welds were mainly made by submerged arc welding.

What was apparent was that reasonable liberalization does not result in significant repair reduction where the weld is of general good quality. It should be realized that all the above opinions are based on preliminary work and larger sampling is required before definite conclusions should be drawn. In addition, it would be interesting to survey the weld quality of ships built with current technology and make detailed comparisons between automatic versus semi-automatic or manual welding techniques.

The next part of the paper will be directed toward visual acceptance standards. For all major structures under construction, most of the weld inspection has to be visual. This involves looking at fillets and butts in various sections of ships. Our objective in developing visual acceptance standards was to clarify standards that can be more meaningful to the designer and regulator who specify standards and to the inspector who interprets the standards in the field. Visual acceptance standards should provide uniformity and reproducibility and be adaptable to codes. In addition, samples should be available which illustrate gradations of weld surface quality that are suitable for different applications. A review of available codes indicates that, in many cases, even though attempts are made to define surface appearance quantitatively, we find that the judgements of actual production welds must be subjective. There doesn't seem to be any suitable way to literally specify surface appearance that can relate to actual production welds.

We believe that visual acceptance reference standards could be useful to shipyards for internal standards, regulatory bodies for Rules and inspection, government agencies for specifications, owners and designers for their inspection and contracts and to technical societies. Eventually we hope these will prove useful for incorporating into specifications. An important objective is to acquire a universal understanding. Translation of a code into a foreign language very often could change the context of what is acceptable and not acceptable. Having an actual specimen to examine transcends all language difficulties.

The range of qualities of samples was determined after existing descriptive standards were surveyed. Our approach was to obtain samples of various surface irregularities with three gradations of quality which could ultimately

be selected for reference standards. Qualities selected were that which was interpreted as the average of acceptance specifications, one somewhat better in quality and one somewhat poorer. In the future, these could be made available as plastic models which could be widely distributed so that those concerned could physically see what the words of the specification are trying to describe.

The work was done by ABS under the auspices of the SNAME SP-7 Panel which consists of representatives of shipyards, ABS, Navy, Coast Guard, and MarAd. Seven shipyards contributed 350 samples of which 18 were finally selected as the reference standards. These samples were prepared using shielded metal *arc*, submerged arc, gas metal arc, and flux cored arc welding. Samples of undercut, scattered porosity and cluster porosity were categorized. The program was authorized in 1980. The major part of the time was spent in acquisition of the samples and it took almost a year with numerous discussions to get an agreement on the selection of the 18 reference samples. The 18 reference samples each 6 in. long consist of butts and fillets with 3 gradations of undercut, scattered porosity and cluster porosity. The 3 gradations are categorized in increasing severity as Classes A, B, and C. (See Table D). Figures A through F show the various samples with close-up enlargements of the irregularities. It is evident that it is very difficult to describe the irregularities in words.

In addition to reference standards, we provided tentative definitions or descriptions which might be considered, for adoption by industry and the codes. The initial program has been completed and the samples have been delivered to the SP-7 Panel which is arranging to have plastic models of the samples available. In the near future, comments will be solicited from industry, ABS and various regulatory agencies. After comments have been received and taken into account, the standards will be suitable for consideration by industry for adoption in their codes, Rules and specifications.

A follow up effort will be proposed to acquire samples for categories of other surface irregularities. One condition is roughness which is height differences within beads. Another is contour which includes overlap and re-entry angle.

We hope that this effort will minimize an area of controversy and eliminate an area that has been an irritant to many of the marine industry.

Table A Nondestructive Testing Acceptance Criteria

| | AT INTERSECTIONS | | BETWEEN INTERSECTIONS | | | |
|---|---|---|---|---|---|---|
| | Within Midship 0.6L | Outside Midship | Within Midship 0.6L | | Outside Midship | |
| | | | Butts | Seams | Butts | Seams |
| ABS Rules | A | B | — | — | — | — |
| ABS Guidelines | A | B | 2A | 2B | 2B | 2B |

Table B UT SURVEY—18 SHIPS 400-600 FT.

| Type | No. | Year Built | Ships with recordable indications No. | Ships with recordable indications Year Built |
|---|---|---|---|---|
| Containers | 3 | '69(2), '73 | 1 | '69 |
| Freighters | 9 | '45(2), '52, '57, '59 '60(2), '61, '62 | 2 | '52, '59 |
| Tankers | 1 | '43 | 1 | '43 |
| Transports | 5 | '44(3), '45(2) | 3 | '44(2), '45 |
| | 18 | | 7 | |

TABLE C

RESULTS OF UT SURVEY (18 SHIPS)

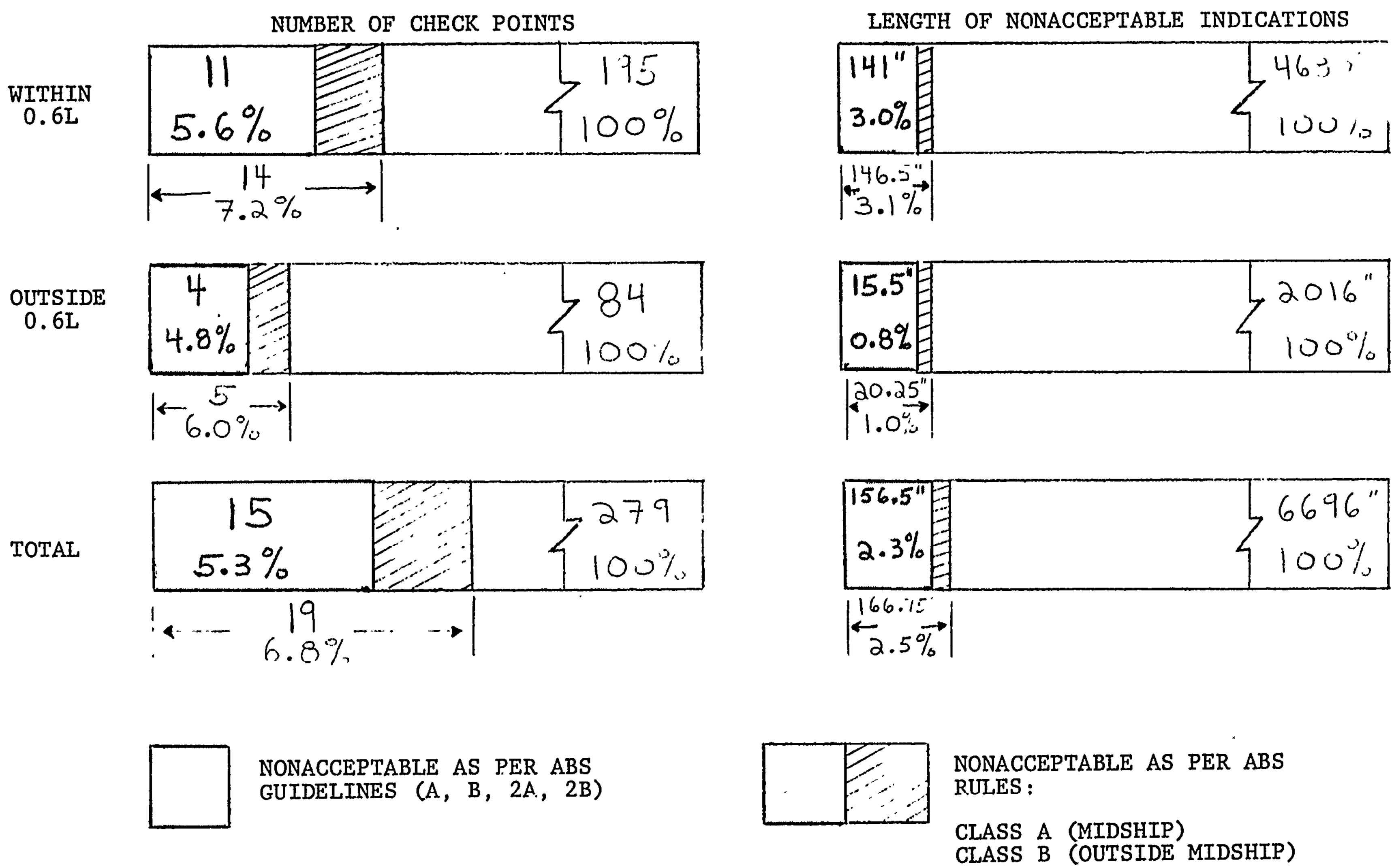


Table D **REFERENCE STANDARD CATEGORIES**

**(Butts and Fillets)**

## UNDERCUT

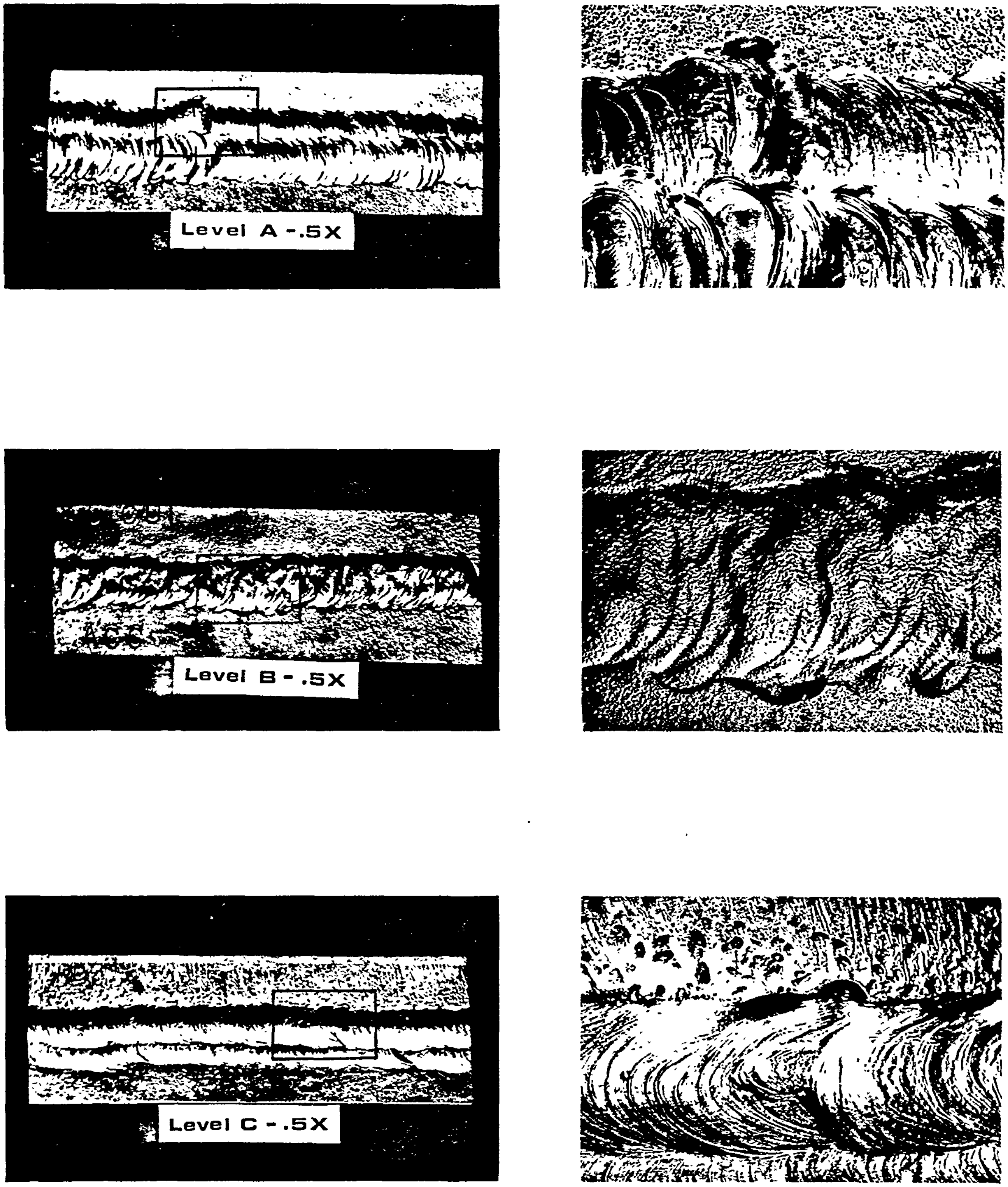
- Class A- 1/64 in. continuous
- **Class B-1/32 in. continuous**
- **Class C-1/16 in.** continuous

**SCATTERED POROSITY**

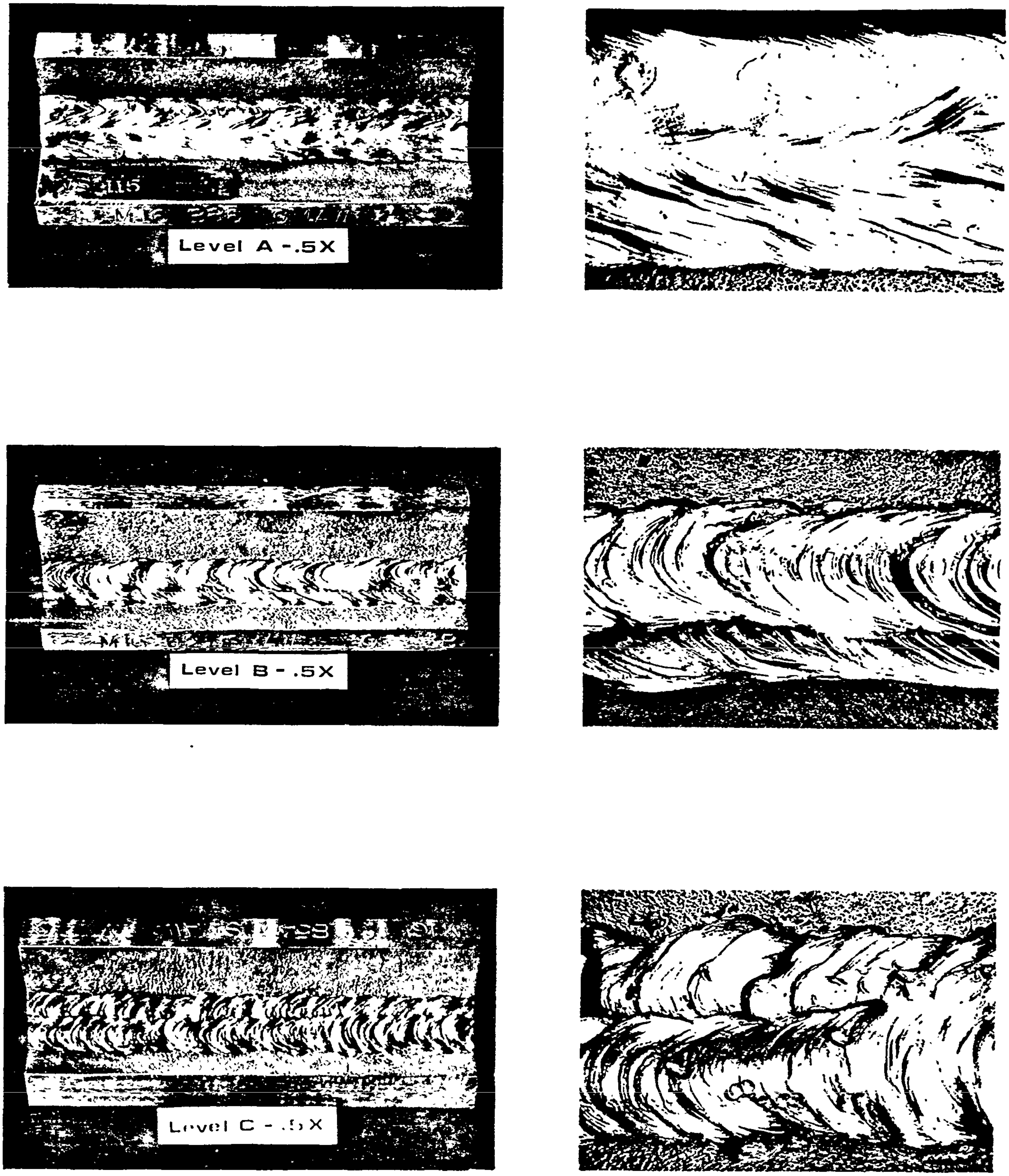
- Class A-4 pores **(1/32 in.** max.)
- **Class B-4 pores (1/16 in. max.)**
  or 7 pores (3/64 in. max.)
- Class C-4 pores (1/8 in. max.) or equivalent area

CLUSTER POROSITY

- **Class A-multiple pores (1/32 in.** max.)
  **within 1/4 inch-**
- Class B-multiple pores within **1/2 inch**
- Class C-multiple pores within 1 inch




# FIG. A: Undercut




# FIG. B: Undercut

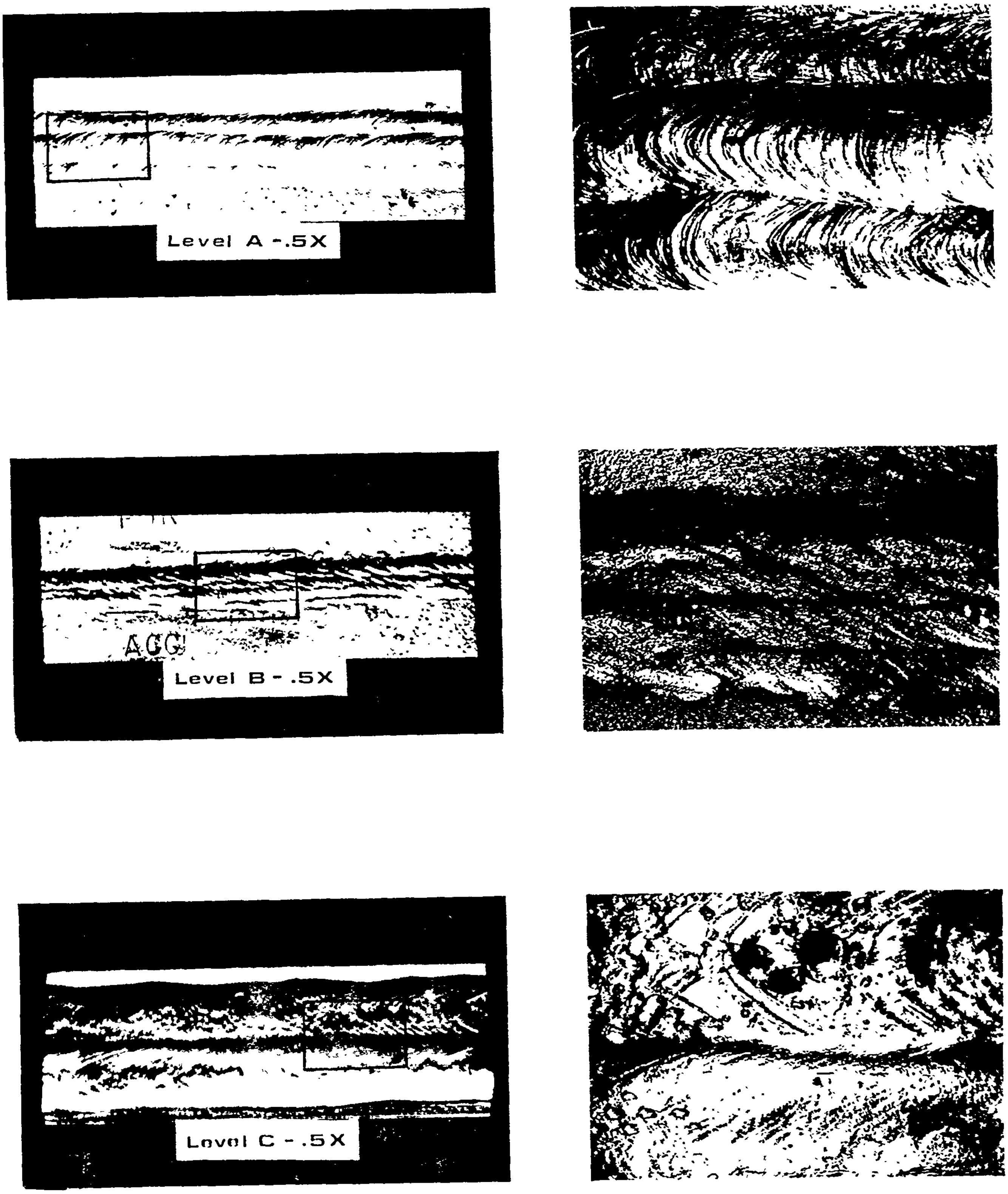



**FIG.C: Scattered Porosity**

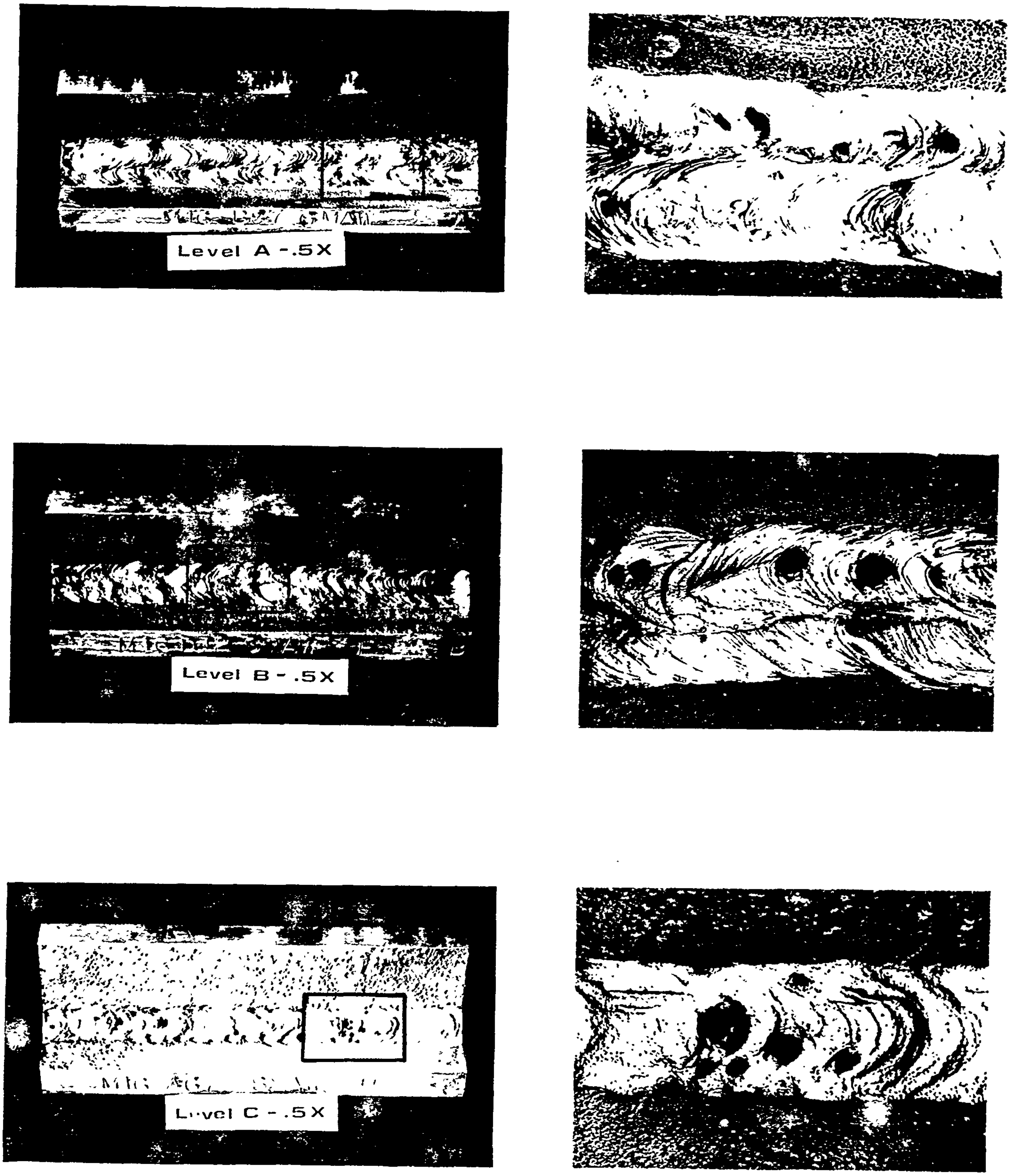



**FIG.D: Scattered Porosity**

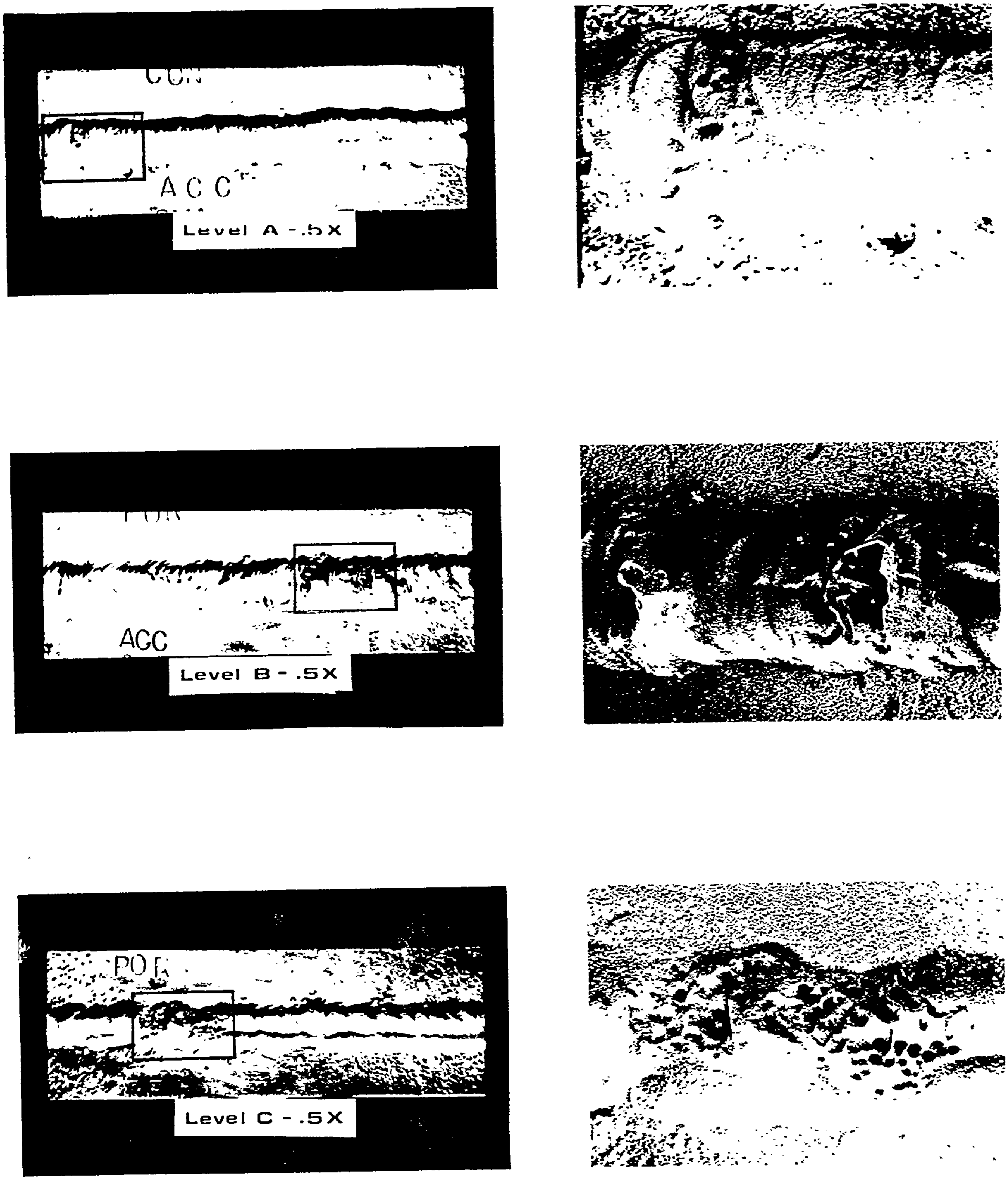



**FIG.E: Cluster Porosity**

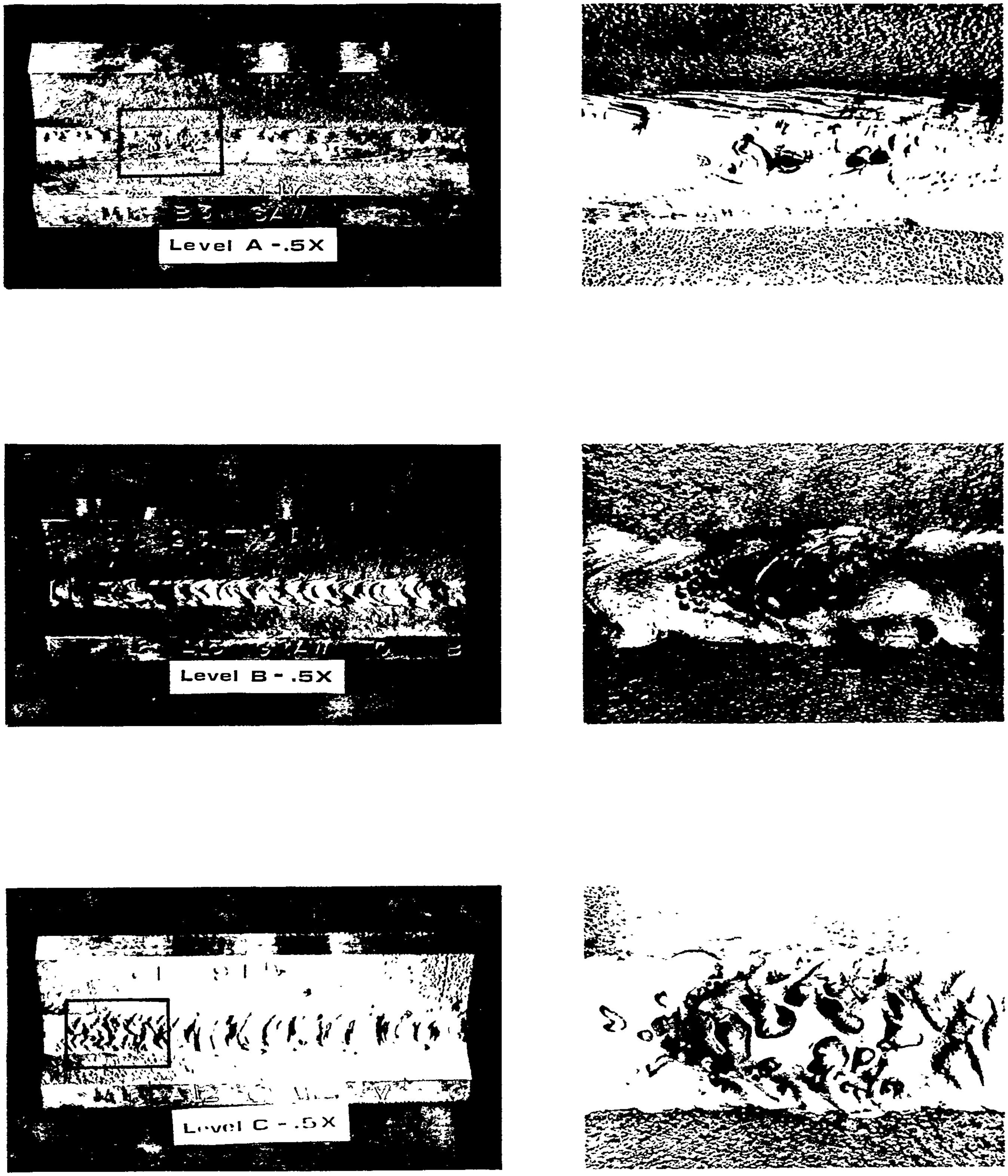



**FIG. F: Cluster Porosity**

# APPLICATION OF SHIPOPT TO PRELIMINARY DESIGN OF COMMERCIAL SHIPS

Colin S. Moore
Naval ARchitect
Giannotti & Associates Incorporated
Berkeley, California

Mr. Moore has over 5 years experience in the design of vehicles and platforms for the marine environment. He is actively involved in ocean platform and ship design and analysis, including development and evaluation of platform concepts for shelf-mounted ocean thermal energy conversion (OTEC) systems, and has been involved in various ship design and modification projects, structural engineering calculations, including finite element analysis procedures and intact and damaged stability studies.

Mr. Moore holds a BS degree in physics and astronomy from the University of British Columbia, and a MS degree in naval architecture from the University of California at Berkeley. He is a member of SNAME.

Allan T. Maris
Chief Engineer
Giannotti & Associates Incorporated
Berkeley, California

Mr. Maris has provided engineering design, analysis and management services to the commercial and U.S. government shipping organizations for nearly 20 years and has extensive experience in design and analysis of submersibles for the U.S. Navy, Ocean Thermal Energy Conversion (OTEC) platforms and cold water pipes for the U.S. Department of Energy, tank ships for Chevron Shipping and cargo ships for Farrell Lines and the Trust Territories of the Pacific.

Mr. Maris holds a Professional Engineers License in Naval Architecture and Marine Engineering from Washington State, a bachelors degree (naval architecture/marine engineering) from the University of Michigan, a masters of engineering degree (naval architecture) from the University of California, and has completed business management studies at the University of California. He is a member of the American Bureau of Shipping Special Committee for OTEC and the Society of Naval Architects (Northern California) Executive Committee.

## ABSTRACT

The theory and results of applying computer-aided ship structure optimization procedures to design of a.new.ferry for southwestern Alaska routes is presented, and.is called SHIPOPT. It has been developed by Professor Owen Hughes of the University of New South Wales, Australia, and has had recent application by Giannotti and Associates Inc, to structural design of U.S. Navy ships. Ship optimization is a rationally based, interactive procedure which recognizes prescribed design constraints and optimizes within those constraints ship structural scantlings and geometry for strength, weight, and cost. The structural constraints typically considered are allowable shear and bending stresses, buckling loads, fatigue life, weight, and ship arrangements, based on commercial or regulatory body requirements.

1) SCOPE

2) METHODOLOGY

3) APPLICATION (GENERAL) OF SHIPOPT

4) APPLICATION (SPECIFIC) OF SHIPOPT

5) ACCESSIBILITY/HARDWARE REQUIREMENTS

SHIPOPT PROVIDES:

- A RATIONALLY BASED TOOL FOR PRELIMINARY SHIP DESIGN THROUGH;
- A FAST, EFFICIENT, LOW COST, STRUCTURAL ANALYSIS AND OPTIMIZATION PROGRAM WHICH;
- ALLOWS DESIGNER INPUT OF SAFETY AND FUNCTIONAL CONSTRAINTS AND OPTIMIZATION MEASURES OF MERIT,

RATIONALLY BASED PRELIMINARY
STRUCTURAL DESIGN

1) RESPONSE ANALYSIS

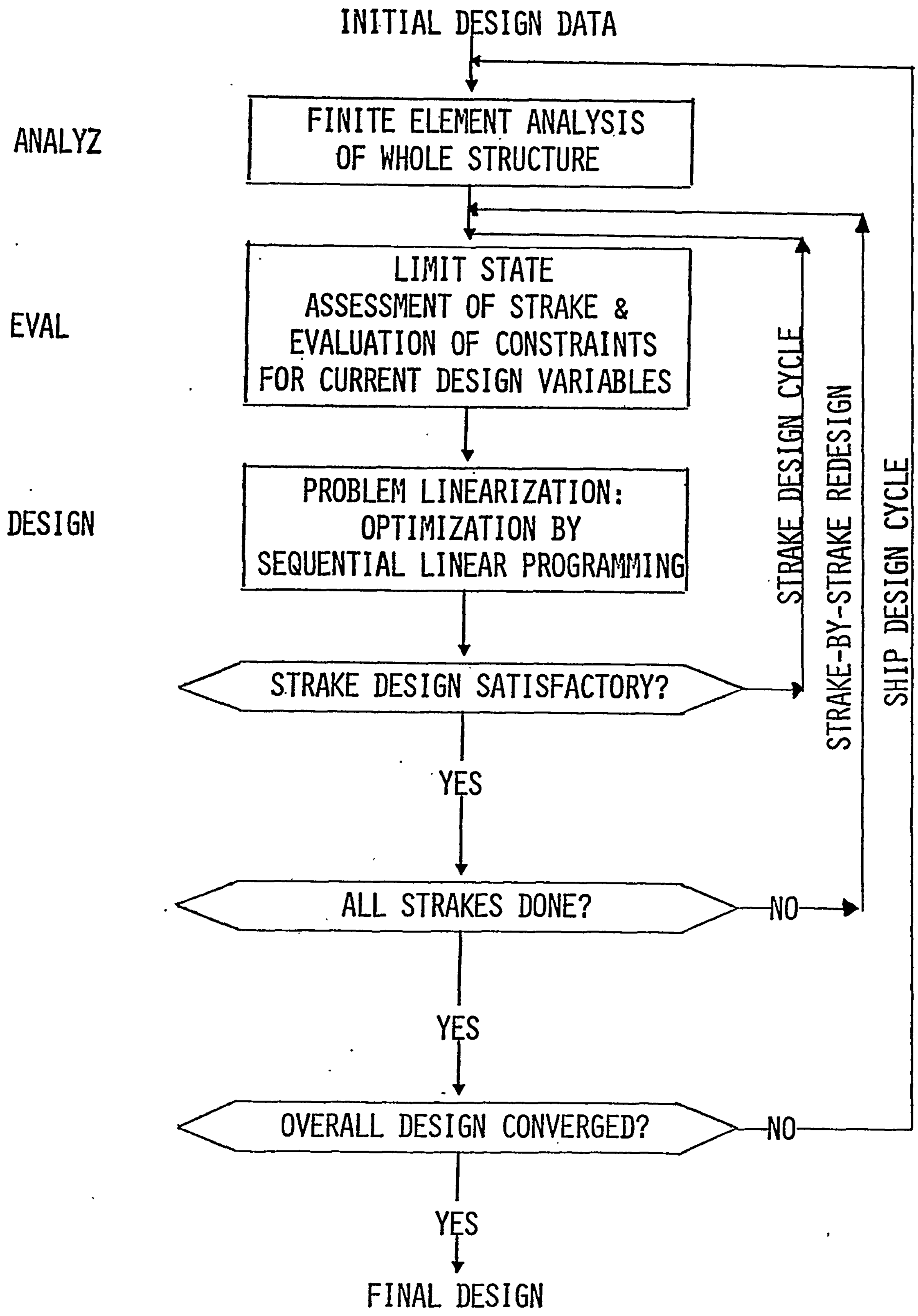
2) CAPABILITY (OR LIMIT STATE) ANALYSIS

3) RELIABILITY BASED STRENGTH CRITERIA

4) NONSTRUCTURAL CRITERIA

5) OPTIMIZATION

6) INTERACTIVE MODE OF OPERATION


INITIAL DESIGN DATA
ANALYZ
FINITE ELEMENT ANALYSIS OF WHOLE STRUCTURE
EVAL
LIMIT STATE ASSESSMENT OF STRAKE & EVALUATION OF CONSTRAINTS FOR CURRENT DESIGN VARIABLES
DESIGN
PROBLEM LINEARIZATION: OPTIMIZATION BY SEQUENTIAL LINEAR PROGRAMMING
STRAKE DESIGN SATISFACTORY?
YES
ALL STRAKES DONE?
NO
YES
OVERALL DESIGN CONVERGED?
NO
YES
FINAL DESIGN
STRAKE DESIGN CYCLE
STRAKE-BY-STRAKE REDESIGN
SHIP DESIGN CYCLE

## APPLICATION (GENERAL) OF SHIPOPT

- BENEFITS
- LIMITATIONS
- STARTING POINT
- RESULTS

## BENEFITS (OF STRUCTURAL ANALYSIS>

- STRUCTURAL ASSESSMENT AND DESIGN REVIEW
- INVESTIGATION OF SAFETY FACTORS
- INVESTIGATION OF ALTERNATIVE DESIGN LOADS
- ASSESSMENT OF STRUCTURAL DAMAGE OR CORROSION

## BENEFITS (OF OPTIMIZATION)

• FIRST ORDER
  - REDUCED COST AND WEIGHT
  - INCREASED PERFORMANCE (E.G., LOWER VCG)
  - COST VS. WEIGHT

• SECOND ORDER
  - REDUCED WEIGHT IMPLIES LOWER RESISTANCE THUS LOWER MACHINERY WEIGHTS

• THIRD ORDER
  - REDUCED MACHINERY WEIGHT IMPLIES FURTHER REDUCTION IN LOCAL SCANTLINGS, OVERALL WEIGHT, RESISTANCE AND COST

## SHIPOPT ABILITIES

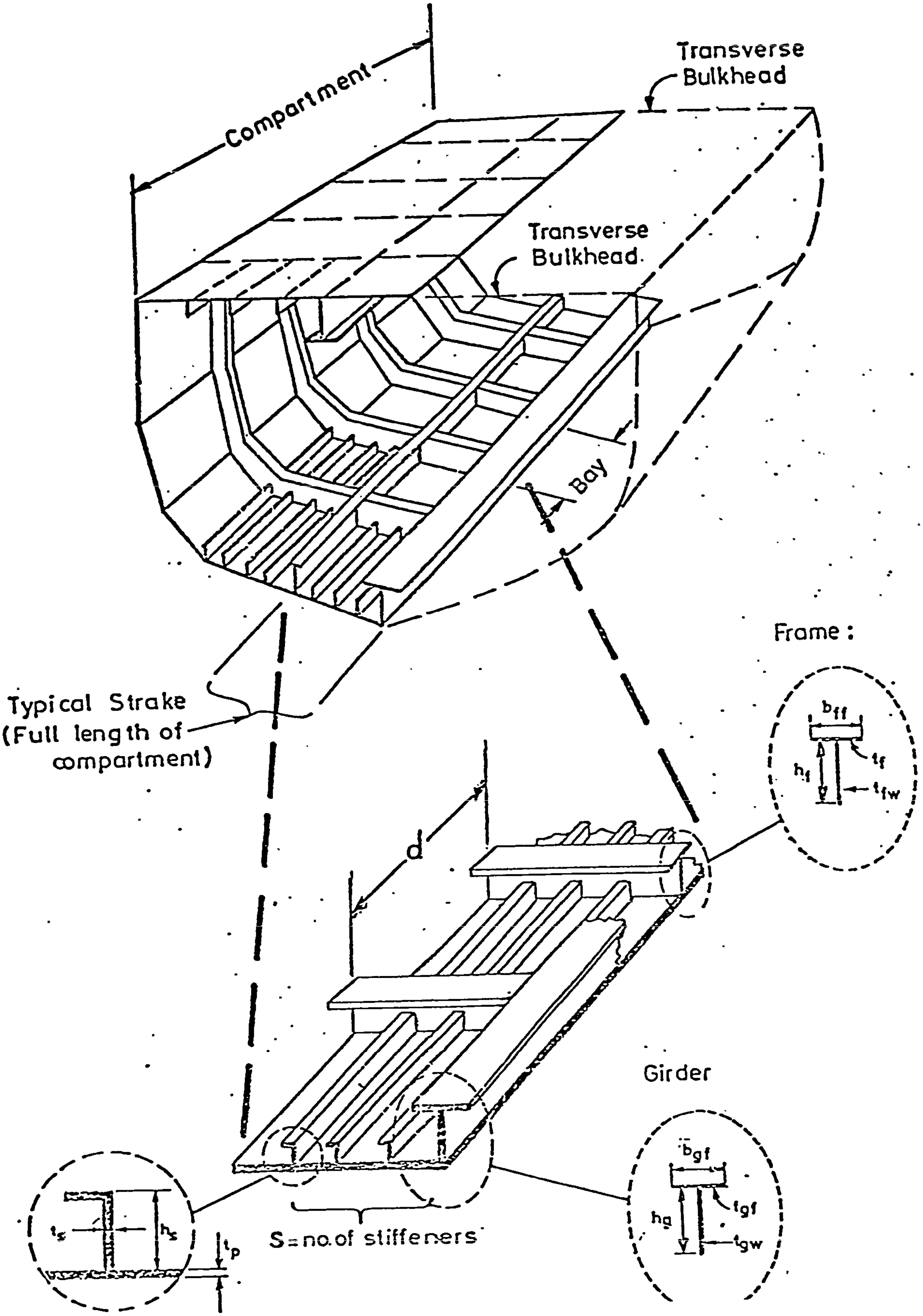
- COMPREHENSIVE 3-D STRUCTURAL ANALYSIS AT EACH STAGE
- EXPLICIT CALCULATION OF ULTIMATE STRENGTH OF ALL PRINCIPAL MEMBERS
- FAST CYCLE TIME
- ABILITY TO REPEAT A PRELIMINARY DESIGN
- ALTERNATIVE STRUCTURAL CONFIGURATIONS
- STANDARD SECTIONS
- USER DEFINED MEASURE OF MERIT; CONSTRAINTS

## LIMITATIONS

- PRISMATIC MODEL
- SYMMETRIC ABOUT ℄
- STATIC OR QUASI-STATIC LOADING ONLY

## STARTING POINT

- LOADS
- STRUCTURAL DEFINITION
  - STIFFENERS AND PLATES
  - STRAKES
  - BHDS,
  - MODULE
- CONSTRAINTS
- PARTIAL SAFETY FACTORS


Compartment
Transverse Bulkhead
Transverse Bulkhead
Bay
Frame :
Typical Strake (Full length of compartment)
d
Girder
S = no. of stiffeners

## RESULTS

- ANALYSIS
  - NODAL DEFLECTIONS
  - STRESSES
  - MINIMUM CONSTRAINTS FUNCTION LOCATION IN STRAKE
  - STATISTICAL FEASIBILITY SUMMARY

## RESULTS

- OPTIMIZATION
  - CONSTRAINT FUNCTION VALUES
  - ACTIVE CONSTRAINTS
  - STATISTICAL FEASIBILITY SUMMARY

## APPLICATION (SPECIFIC)

- TEST CASES
- ALASKA FERRY
  - **HULL CUTOUTS**
  - **VEHICLE DECK**
  - **SUPERSTRUCTURE**
  - **EXTREME HEAVY WEATHER**

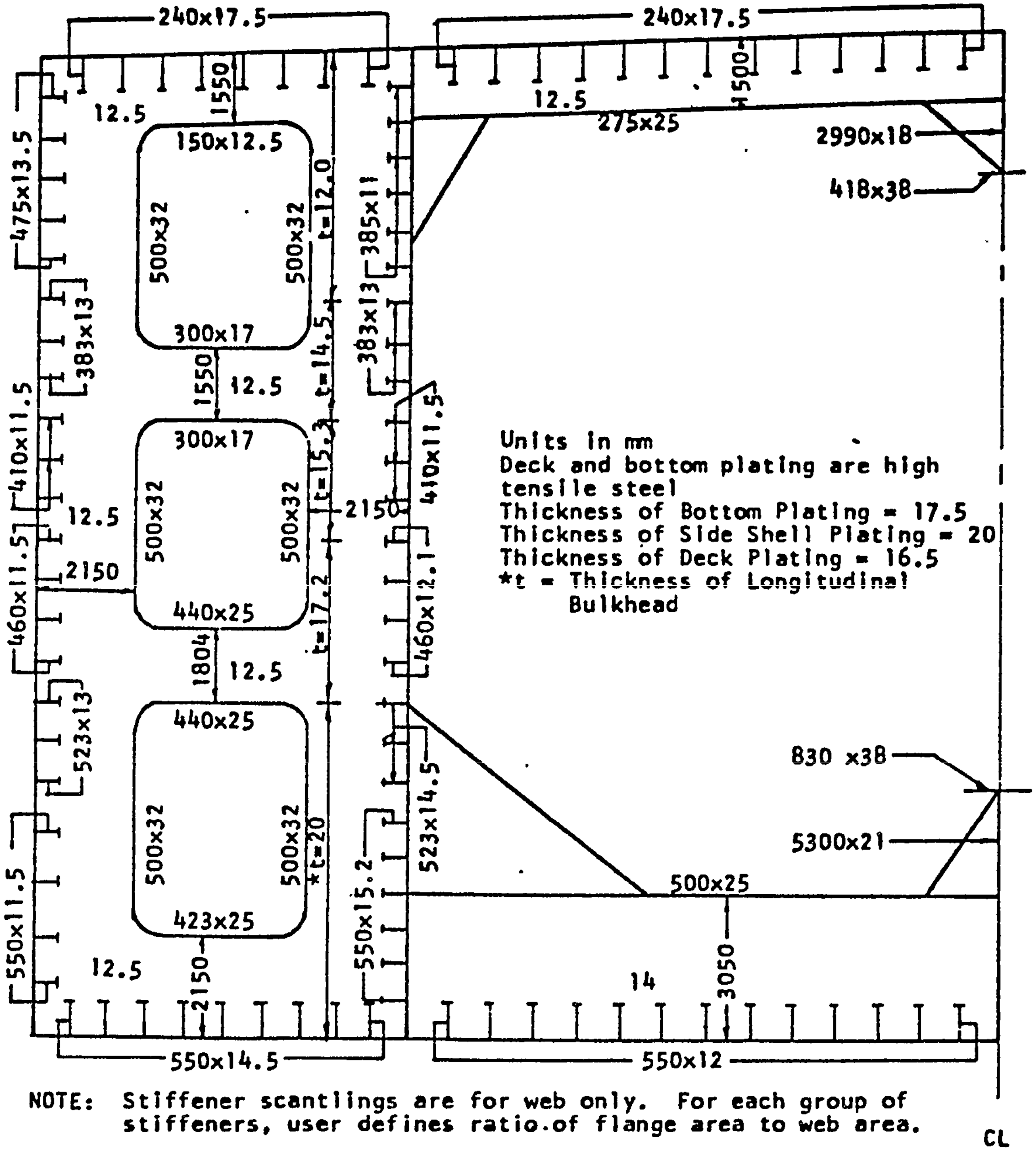



**Fig. 6** Initial tanker scantlings

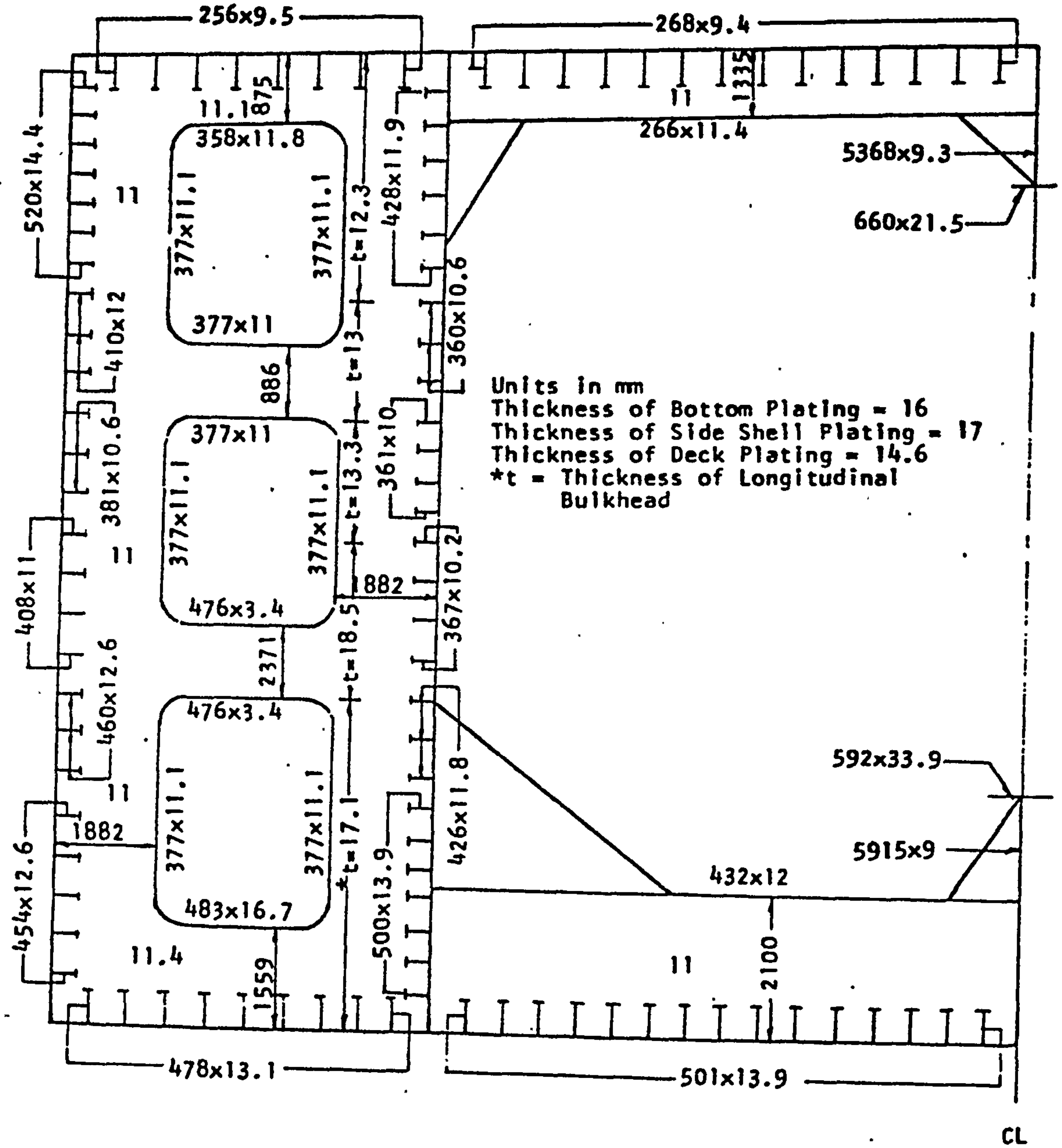



**Fig. 7** Final tanker scantlings

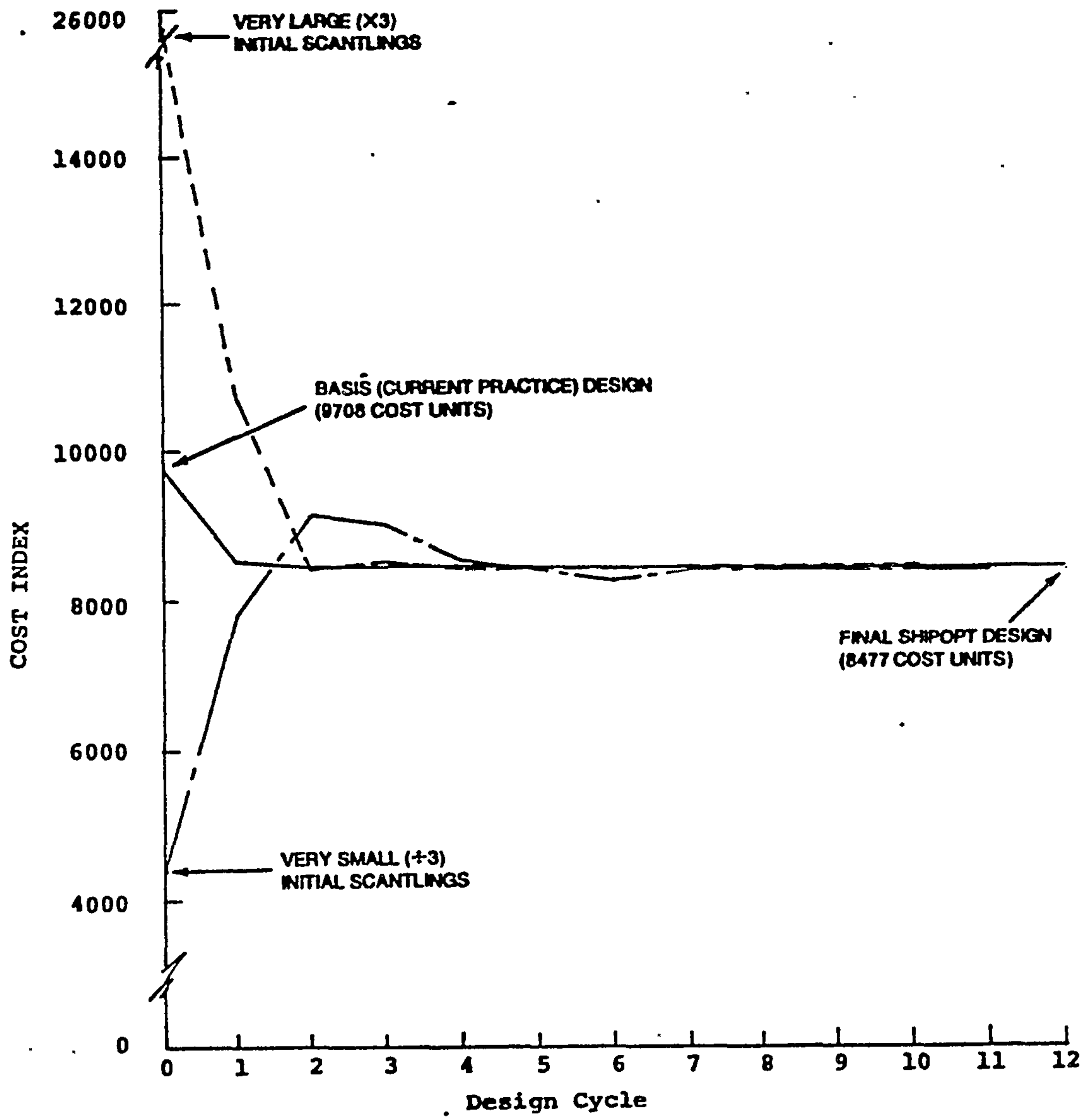
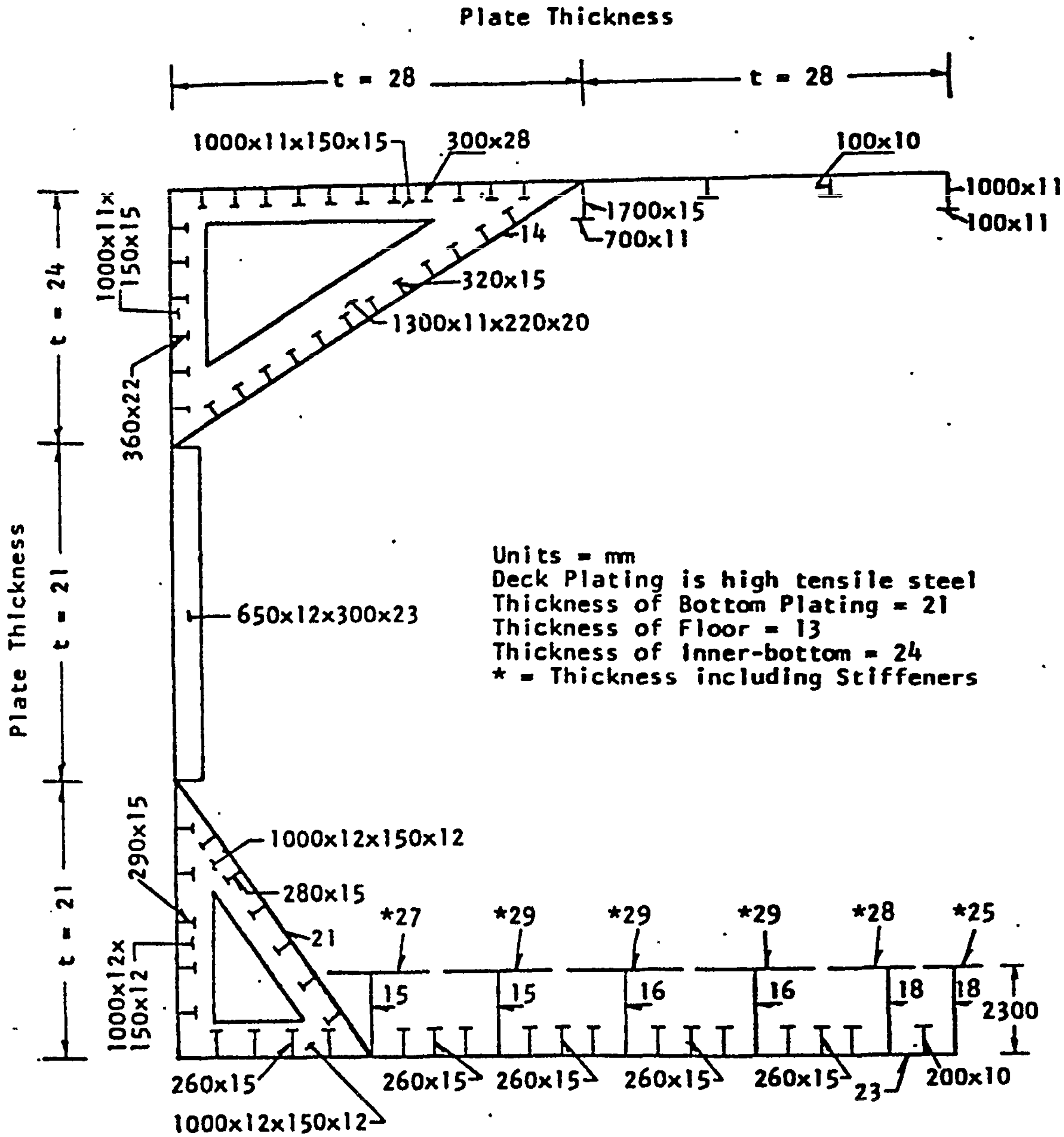



Fig. 5 Convergence and stability of SHIPOPT




NOTE: Stiffener scantlings are for web only. For each group of stiffeners, user defines ratio of flange area to web area.

Fig. 9 Initial bulk carrier scantlings

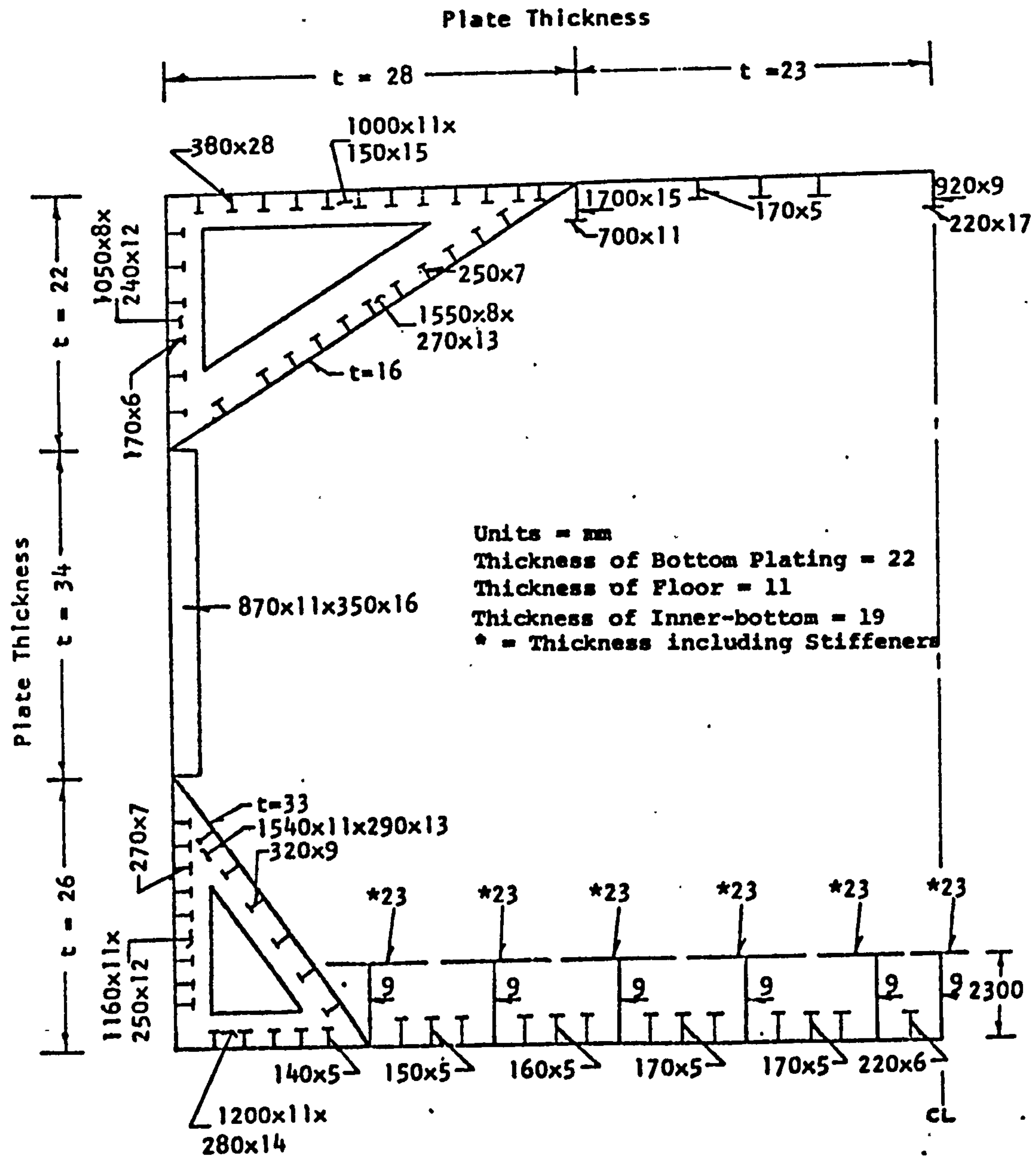



Fig. 10 Final bulk carrier scantlings

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**HARDWARE**

1) MAIN FRAMES

2) "SUPER-MINI ,

ACCESSIBILITY

**1) OWEN HUGHES**

2) GIANNOTTI & ASSOCIATES

# STANDARDIZATION AND INTEGRATION OF SHIPYARD PROCESSES AND PROCEDURES


Captain James Ronald Fisher
Engineering Duty Officer
Industrial Facilities Management Directorate
Naval Sea Systems Command
Washington, D.C.


Captain Fisher is currently serving a second tour. As a line officer, he served in a destroyer, four different attack and fleet ballistic missile submarines and as the training officer of one of the nuclear power training units. As an ED, he served at Charleston Naval Shipyard, and at NAVSEA as the assistant Ship Logistics Manager for SSN's and as Head of the Resources Planning Division.

Captain Fisher is a member of the Naval Institute, The American Society for an Engineering Education, and The Institute of Industrial Engineers. He is on the Education and Industrial Engineering Panels of the Ship Production Committee of SNAME. He is also a member of ASNE and was Chairman of the Charleston Chapter in 1976-77. He is a graduate of the U.S. Naval Academy and the Industrial College of the Armed Forces and has a MA degree in Business Management.


## ABSTRACT

NAVSEA's ongoing efforts to improve, standardize and integrate shipyard process instructions are outlined. This plan, will combine the best features of various DOD, Navy and Private programs including for example: (1) the navy technical information presentation programs, (2) DOD computer aided time standards, (3) Navshipyd/Ordnance Station EM&S automated support (NEAS), (4) the Carnegie Mellon/USS CARL VINSON CUN 70 ZOG program, (5) shipboard nontactical ADP system (SNAP), (6) NAVSHIPYD Norfolk - work planning and control systems - PROMPT, and (7) technical repair standards (TRS) program. Specific aspects of these programs will be discussed including computer aided authoring, group technology, and common vocabularies, and a status report of these efforts as well as future plans will be provided.

"IT'STIME FOR CHANGE IN THE WAY WE BUILD SHIPS"

,,,BANGS,,,IREAPS

## OBJECTIVES

- STANDARDIZE & AUTOMATE PROCESSES & PROCEDURES FOR SHIPYARD WORK
- INCORPORATE BEST FEATURES OF EXISTING & FUTURE AUTOMATED DATA INPUT, STORAGE & RETRIEVAL PROGRAMS

## SHIPYARD PROCESS INSTRUCTION

- AN AID FOR THE MECHANIC THAT GIVES HIM CONFIDENCE IN THE FACT THAT HE IS DOING A JOB CORRECTLY AT A REASONABLE RATE AND UTILIZING THE RIGHT TOOLS AND MATERIAL.
- A LOGICAL COLLECTION OF BOTH OPTIONAL AND MANDATORY TECHNICAL INFORMATION AND GUIDANCE FOR PERFORMING WORK, SUCH AS OVERHAULING A PUMP, WELDING A SEAM, FABRICATING A JOINER BULKHEAD.
- A FRAMEWORK THAT A SHIPYARD SHOULD BE ABLE TO USE TO ORGANIZE ITS WORKFORCE, FACILITIES, EQUIPMENT, AND MATERIAL IN AN EFFICIENT MANNER FOR A PARTICULAR TASK.
- A LOGICAL FRAMEWORK FOR PRODUCTIVITY IMPROVEMENTS.

## GOALS

- COMMON FORMAT FOR PROCESSES, PROCEDURES, ALTERATIONS, ETC.
- ONE PRINT OUT YIELDS ALL INFORMATION NEEDED TO PERFORM THE JOB AND NO UNNECESSARY INFORMATION
- ABILITY TO EXTRACT WORKSHEET THAT CONTAINS ALL DATA COLLECTION TAG OUT, SAFETY, ETC. REQUIREMENTS
- ELIMINATE CODES & VAGUE ACRONYMS & PRINT INFORMATION IN CLEAR TEXT
- INFORMATION RECORDED IN ONLY ONE LOCATION
- ALL DATA NEEDED ON THE SUBJECT PRINTS OUT ON ONE INQUIRY

## DESIRED RESULTS

- EASY TO USE
- INCREASED EFFICIENCY BY STANDARDIZING OPERATIONS
- ADAPTABLE TO PLANNING, ESTIMATING, BUDGETING, TRAINING, ETC.
- INTERFACE WITH OTHER SYSTEMS:
  - SPECIFICATIONS & STANDARDS
  - SUPPLY
  - 3M
  - QUALITY ASSURANCE
  - TRAINING
  - FACILITIES, TOOLS, SHIPYARD MODERNIZATION, MILCON ETC.

## SHIPYARD PROCESSES

SHIPYARD PROCESSES INCLUDE SPECIFIC EQUIPMENT, COMPONENT, MODULE OR SYSTEM FABRICATION, OVERHAUL, REPAIR MAINTENANCE, MODIFICATION AND TEST PROCEDURES

THESE PROCEDURES CAN BE BROKEN DOWN INTO GENERIC PROCESSES SUCH AS PAINTING, WELDING, SILVER BRAZING, PIPEBENDING, ETC.

## PROCESS & PROCEDURE INSTRUCTION

PERSONNEL REQUIREMENTS AND TIME ESTIMATES

WORK TO BE DONE

SPECIFICATIONS

DRAWINGS, SKETCHES CAD/CAM

STEP BY STEP PROCEDURE

MATERIAL (KITS, PARTS, CONSUMABLES, ETC.)

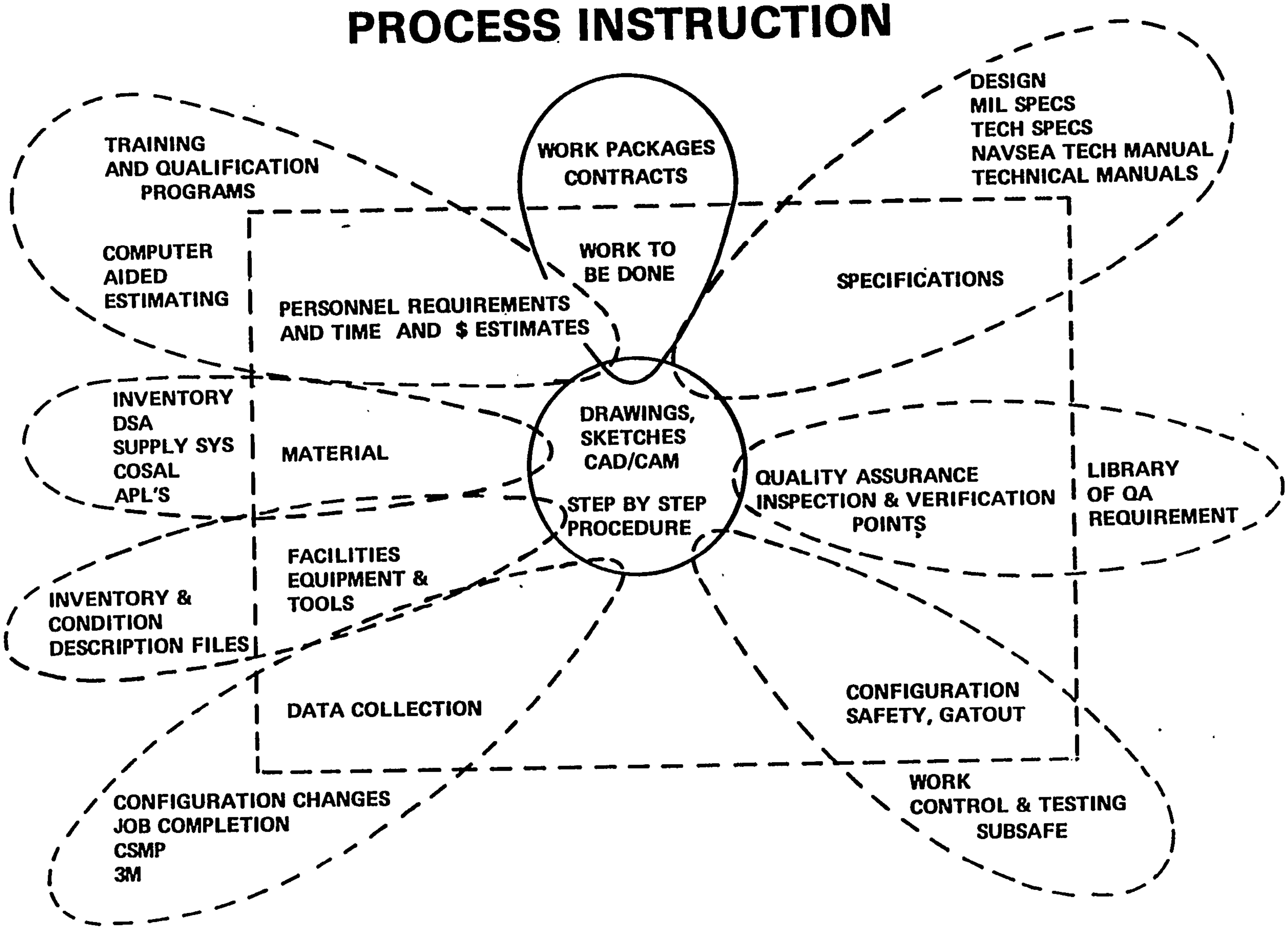
QUALITY ASSURANCE INSPECTION & VERIFICATION POINTS

FACILITIES EQUIPMENT & TOOLS

DATA COLLECTION

CONFIGURATION SAFETY, TAGOUT

# INTEGRATED PROCESS INSTRUCTION



# PROCESS & PROCEDURE STANDARDIZATION TEAM

CAPT RON FISHER
SEA 07Z/070Z
COORDINATOR

MR RON SHARBAUGH
SEA 070K
PRODUCTIVITY

MR SAM RAINEY
DTMB
NTIPS PROJECT MANAGER

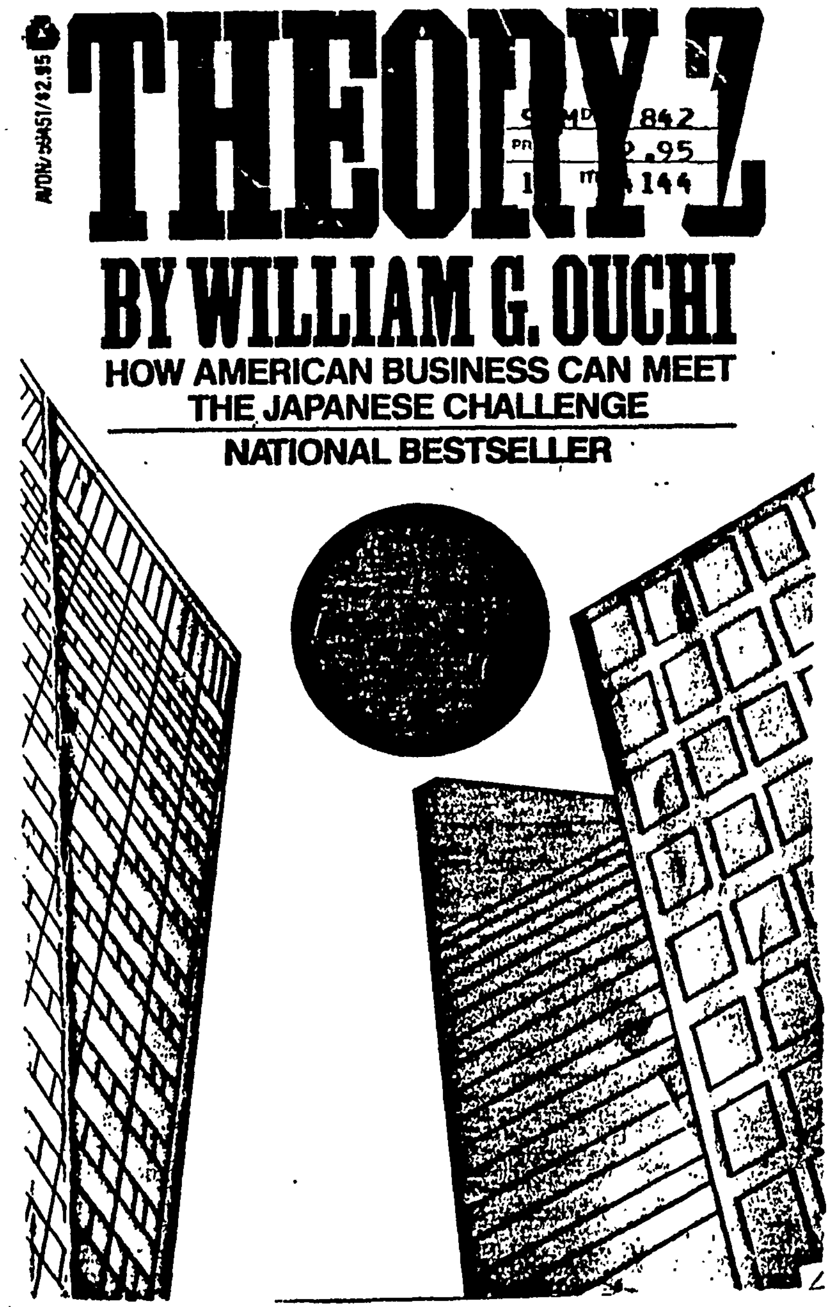
MR VIC BURNETT
NAVSEA
SPECIFICATIONS & STANDARDS

CAPT BOB SULIT
SEA 070 STAFF
NEAS PROJECT MANAGER

MR HARRY DASHIELL
DOD PRODUCTIVITY OFFICE
CATS PROJECT MANAGER

JOHN HARTIGAN
SEA 072
SHIPYARD SKILLS TRNG

CAPT JAY WHEELER
SEA 07D
SUPPLY/MATERIAL




"HERE, FINALLY, IS A BOOK THAT EXPLAINS, IN FUNDAMENTAL TERMS, WHY PRODUCTIVITY IN JAPAN IS SO MUCH HIGHER . . . In the years ahead, common use of the term 'Theory Z' will attest to the significant contribution of this important work."
Arjay Miller, Director, Ford Motor Company

"The Buick assembly plant in Flint, Michigan, used the Theory Z approach . . . Within two years, the plant had become the most efficient General Motors facility."
*Time*

"Theory Z concentrates on the organizational and behavioral side of management. One of the central tenets is that the traditional adversarial relationship between American management and workers is badly outdated."
*The New York Times*

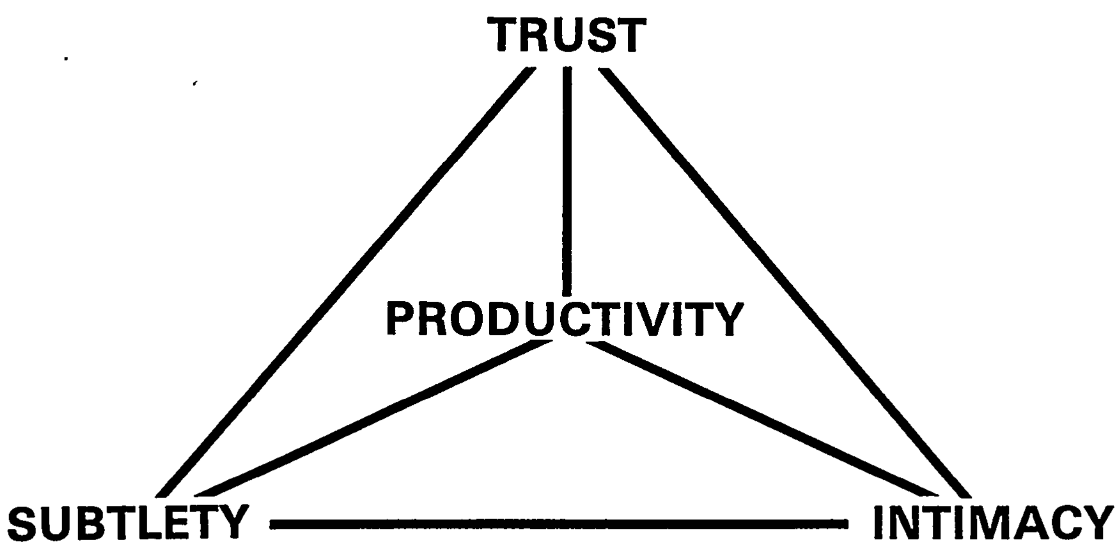
"A hot new plan to revitalize corporate America."
*The Los Angeles Times*

"Powerful answers for American firms struggling with high employee turnover, low morale, and falling productivity."
*Dallas Times-Herald*

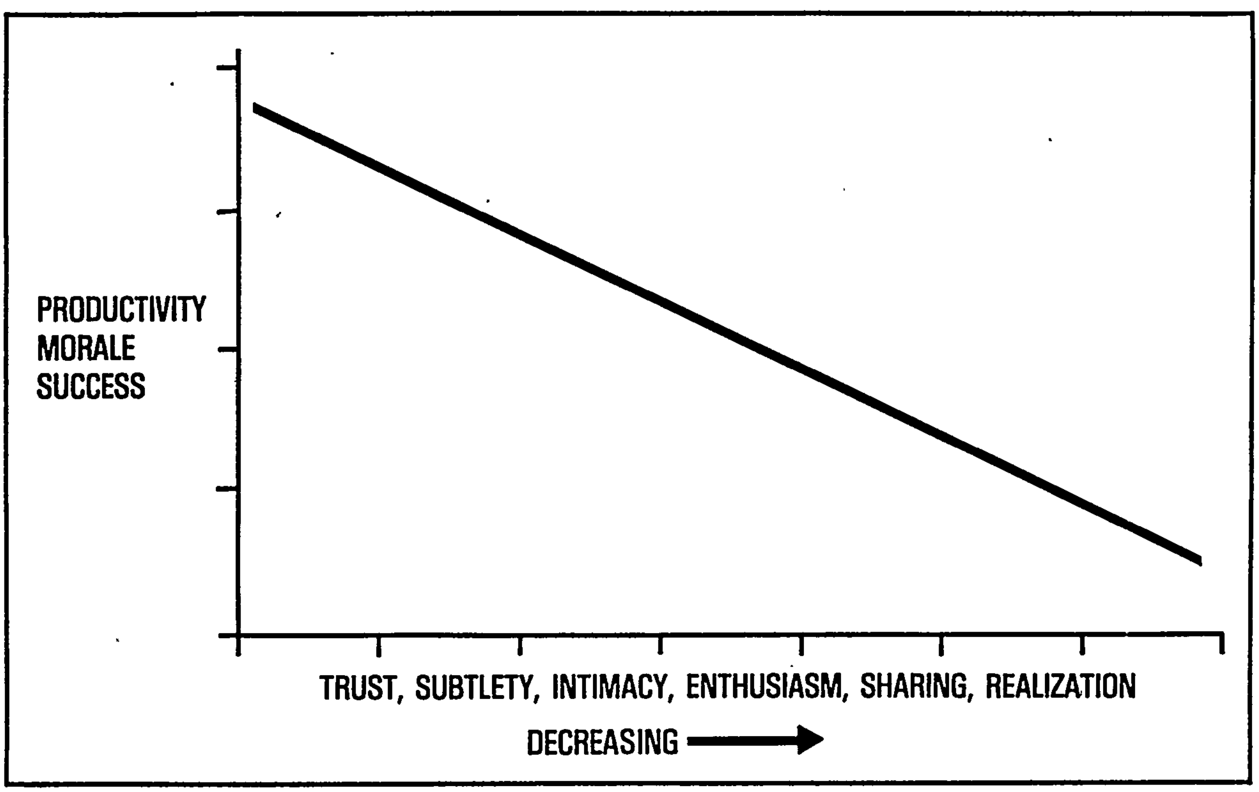
"Combines the best of the American and the Japanese business styles."
Akio Morita, Chairman, SONY Corporation

"Theory Z has to do with important matters—productivity, the welfare of corporations and their employees, and, by extention, the competitiveness of the national economy."
*Fortune*

# LESSONS FROM THEORY Z




# LIFE & WORK



# RELATED EFFORTS AND INITIATIVES

THIS PLAN INTERFACES WITH AND DRAWS ON OTHER ONGOING INITIATIVES

- TECHNICAL REPAIRS STANDARDS (TRS)
- NAVAL TECHNICAL INFORMATION PRESENTATION PROGRAM (NTIPPS) – PROVIDES FORMAT COMPUTER AIDED AUTHORING
- DOD COMPUTER AIDED TIME STANDARDS (CATS) – PROVIDES SEARCH BY WORD; LIBRARY OF ESTIMATED TIME BY PROCESS
- SOCIETY OF NAVAL ARCHITECTS & MARINE ENGINEERS (SNAME) SHIP PRODUCTION COMMITTEE
- MARAD'S INITIATIVES-MOST © AT NNEWS – USED FOR BOTH STUDS & AUTOMATIC/MUST AT BIW ISSUE OF WORK
- MANUFACTURING-SHIPBUILDING TECHNOLOGY (MT/ST) PROGRAM – $1M EBDIV CAD CAM
- SHIPBUILDING STANDARDS PROGRAM
- CARNEGIE MELLON-ZOG-USS CARL VINSON CVN 70 – HUMAN COMPUTER INTERFACE
- SHIPBOARD NON TACTICAL ADP PROGRAM (SNAP) – HONEYWELL HAS CONTRACT
- NAVAL AVIATION LOGISTICS DATA ANALYSIS (NALDA)
- NAVAL AVIATION LOGISTICS COMMAND MANAGEMENT INFORMATION SYSTEM (NALCOMIS) – WILLOW GROVE
- NAVAL SHIPYARD/ORDNANCE STATION ENGINEERED METHODS AND STANDARDS AUTOMATED SUPPORT SYSTEM

# SPECIFIC EQUIPMENT OVERHAUL AND REPAIR PROCEDURES

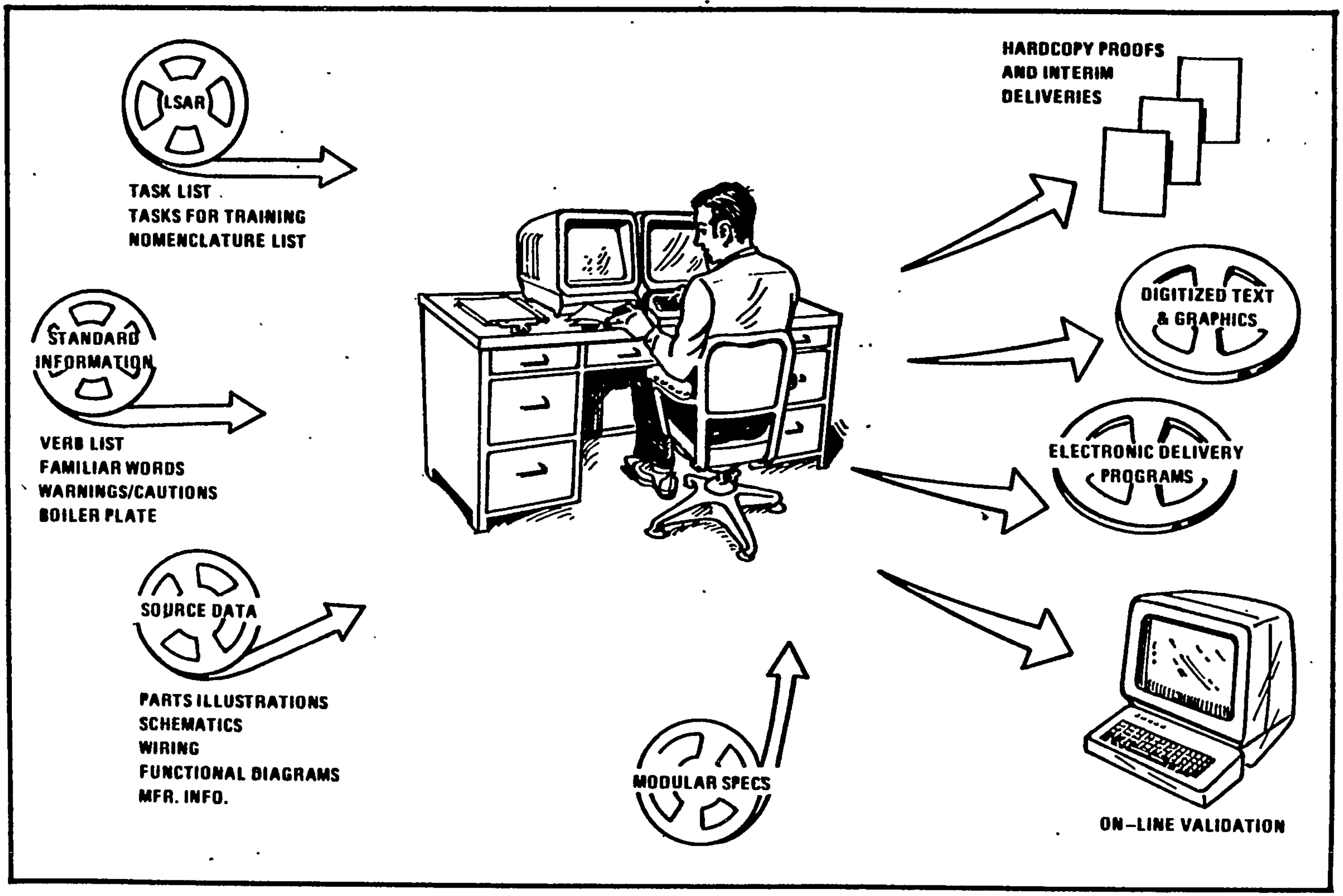
TECHNICAL REPAIR STANDARD (TRS) IS THE TOP LEVEL DOCUMENT

- NAVSEA INSTR 4160.2 PROMULGATED PROGRAM
- NAVSHIPYD NORFOLK COORDINATING PREPARATION EFFORTS OF NAVAL SHIPYARDS
- APPLICABLE TO PUBLIC & PRIVATE YARDS
- WILL BE NON DEVIATION (ND)-WHEN INVOKED FOR CLASS B OVERHAUL
- WILL INCLUDE I & V POINTS
- WILL BE THE PRIMARY NAVSEA DOCUMENT FOR CONDUCTING CLASS B OVERHAULS OF MACHINERY

OTHER PROCEDURES ARE EXPECTED TO EVOLVE INTO TRSs

- METHODS AND STANDARDS, UNIFORM METHODS AND STANDARDS, ENGINEERED METHODS & STANDARDS
- TECHNICAL OVERHAUL PROCEDURES (TOPs)
- STANDARD ITEMS (SI's)
- CLASS STANDARD WORK ITEMS (CSWIs)
- MRCs

# NTIPS COMPUTER–BASED AUTHORING SYSTEM



## NTIPS COMPUTER–BASED AUTHORING SYSTEM

1. PROMPTED INTERACTIVE DATA ENTRY
2. ON–LINE EDITING (FOR TEXT AND GRAPHICS)
3. PROJECT MANAGEMENT AND INDEXING
4. AUTOMATED QUALITY INSPECTION
5. AUTOMATED OUTPUT FORMATTING
6. ACCESS AND SECURITY CONTROL
7. INTERACTIVE COMMUNICATIONS
8. ON–LINE USER TRAINING AND SUPPORT
9. ACCESS TO FLEXIBLE AUTHORING TOOLS

## PROCESS INSTRUCTION VARIABLES

UNDER NTIPPS, NAVY TECHNICAL INFORMATION PRESENTATION PROGRAM, PROCESS INSTRUCTION VARIABLES ARE:

- CONTENT
- FORMAT
- STYLE
- MEDIUM

# CONTENT CONSIDERATIONS

ACCOMPLISHMENT OF SYSTEM-RELATED TASKS REQUIRES INFORMATION OF ONLY FOUR GENERAL TYPES:

1. DESCRIPTIVE – TELLING HOW A GIVEN PART OF A SYSTEM WORKS.
2. PROCEDURAL – TELLING A TECHNICIAN HOW TO DISASSEMBLE A GIVEN COMPONENT OR REPAIR AN IDENTIFIED FAULT.
3. TROUBLESHOOTING – TELLING A TECHNICIAN HOW TO LOCATE THE SOURCE OF A MALFUNCTION.
4. PARTS DESCRIPTION – ILLUSTRATED PARTS BREAKDOWN (IPB) PARTS CATALOGUES, LISTS.

MANY TASKS WILL REQUIRE SOME CONTRIBUTION OF SEVERAL OF THESE TYPES. FOR EACH INFORMATION TYPE, SPECIFIC FORMAT AND STYLE GUIDANCE SHOULD BE PROVIDED.

# FORMAT CONSIDERATIONS

ALL INFORMATION REQUIRED TO PERFORM A TASK SHOULD BE INCORPORATED IN THE SAME SECTION.

- USE TEXT/GRAPHICS MODULES. RELATED TEST AND GRAPHICS MUST BE IMMEDIATELY ADJACENT TO OR INSCRIBED ON THE GRAPHICS.
- TROUBLESHOOTING IS A SPECIAL CASE, REQUIRING LOGIC TREES OR THEIR EQUIVALENT. PROVIDE ALL LOGIC CHAINS AND IMPLICIT DECISION POINTS.
- ELIMINATE ERRORS THROUGH VALIDATION, REPEATED CHECKING AND INSTANT FEEDBACK OF CORRECTED DATA.
- BE SURE PROCEDURES, EQUIPMENT, TOOLS, TEST EQUIPMENT & FACILITIES CALLED OUT ARE/CAN BE MADE AVAILABLE AT THE MAINTENANCE LEVEL INVOLVED.
- PROVIDE FOR WORKSHEET WITH THE MINIMUM INFORMATION REQUIRED TO COMPLETE THE TASK.
- BREAK DOWN INTO LOGICAL TASKS AND SUBTASKS.

## STYLE CONSIDERATIONS

- CALL A GIVEN PART, TOOL, OR ACTION ALWAYS BY THE SAME NAME.
- WRITE THE ENTIRE PROCESS INSTRUCTION USING A CONTROLLED VOCABULARY; I.E., USE ONLY THOSE WORDS ON A PREDETERMINED LIST. NOTE: THE NTIPP OFFICE HAS DEVELOPED A CONTROLLED VOCABULARY MADE UP OF:
  1. A BASIC VOCABULARY
  2. A SPECIALIZED VOCABULARY
  3. A SYSTEM-UNIQUE VOCABULARY
- USE SIMPLE SENTENCES ONLY; NO COMPLEX OR COMPOUND SENTENCES. SAMPLE: REMOVE THE FACEPLATE USING A SCREWDRIVER.

  (NOTE THAT A COMPUTER CAN BE PROGRAMMED TO CHECK FOR COMPLIANCE WITH THE ABOVE RULES.
- USE QUALITY PRINTING, COMPETENT DRAWING STYLE, ETC.

## MEDIUM CONSIDERATIONS

BEST MEDIUM FOR EACH APPLICATION MUST BE ASCERTAINED IN ADVANCE

ELECTRONIC PRESENTATION IS AVAILABLE NOW

COMPUTER DISPLAYED TECHNICAL INFORMATION

- CAN BE VERY INTERACTIVE ON USER–FRIENDLY HARDWARE
- AMENABLE TO LOCAL TAILORING
- APPLICABLE TO BOTH TRAINING AND JOB EXECUTION

MICROFILM USES

- LOOK UP INSTRUCTIONS ON A RELATIVELY INFREQUENT BASIS

MOTON PICTURES – SUITABLE FOR SOME TYPES OF TRAINING

HARD COPY EXAMPLE: CIRCUIT DIAGRAMS

## RELATED EFFORTS AND INITIATIVES (CONT)

- LOGISTICS MANAGEMENT INSTITUTE STUDIES TO EXPLOIT NEW INFORMATION TECHNOLOGY
- NALC 05 – WORKLOAD CONTROL SYSTEM (WCS)
- DOVER AIR FORCE BASE – 436TH MILITARY AIR WING AUTOMATED MAINTENANCE SYSTEM
- NAVSHIPYD MARE ISLAND – NAVSEA MATERIAL INVENTORY, STORAGE AND TRACKING SYSTEM (SEA MIST)
- NAVSHIPYD NORFOLK – WORK PLANNING & CONTROL (PROMPT)
- NATIONAL ACADEMY OF SCIENCE – STUDY OF NAVY ADP NEEDS
- ALL ACTIVITIES – REVISIONS AND UPDATES OF ALMOST ALL MIS AND ADP SYSTEMS

## RELATED EFFORTS AND INITIATIVES (CONT)

- SHIPYARD SKILL TRAINING PROGRAM
- NAVSEA SPECIFICATION UPGRADE PROGRAM
- MODIFIED OVERHAUL PLANNING PROCESS (MOPP)
- SMMSO – SSBN + SSN
- PERA EFFORTS
- DOIP, SOIP, SORT
- EBDIV MANUFACTURING TECHNOLOGY CAD–CAM PROJECT
- LONG BEACH TOTAL INTEGRATED CAD CAM SYSTEM
- MARE ISLAND CAD PROJECTS
- AFLC INTEGRATED COMPUTER AIDED MANUFACTURING PROJECTS
- DEERS
- NAVMAT
- CLASS STANDARD WORK ITEMS

# NEXT STEPS

1. ASSIGN RESPONSIBILITY FOR SPECIFIC PROCESS TO EACH NAVAL SHIPYARD (BELOW ASSIGNMENTS ARE THE SAME AS THOSE FOR THE SKILLS TRAINING PROGRAM).

| | SHIPYARD RESPONSIBLE FOR MODULE TRAINING OEVELOPMENT | NAVSEA TECHNICAL MANUAL | CHAPTER | NAVSEA CODE |
|---|---|---|---|---|
| SHIPFITTING | PORTSMOUTH | 100 | HULL STRUCTURES | 05D |
| | | 623 | LADDERS | 515 |
| | | 624 | ACCESS CLOSURES | 515 |
| | | 625 | WINDOWS PORTLIGHTS & RELATEO EQUIPMENT | 515 |
| | | 633 | CATHODE PROTECTION | 05D |
| WELDING | NORFOLK | 074 | VOL 1 WELDING & ALLIED PROCESSES | 05D |
| SHEET METAL | PUGET | 664 | LOCKS KEYS & HASPS | 515 |
| MARINE MACHINIST | CHARLESTON | 075 | THREADED FASTENERS | 532 |
| | | 076 | GASKETS PACKINGS & SEALS | 513 |
| | | 231 | PROPULSION TURBINES | 522 |
| | | 233 | DIESEL ENGINES | 523 |
| | | | MARINE GAS TURBINES | 523 |
| | | 234 | REDUCTION BEARS | 524 |
| | | 243 | SHAFTING | 524 |
| | | 244 | BEARINGS | 524 |
| | | 245 | PROPELLERS | 524 |
| | | | AUX STEAM TURBINES | 522 |
| | | 502 | | 532 |

| | SHIPYARD RESPONSIBLE FOR MODULE TRAINING DEVELOPMENT | NAVSEA TECHNICAL MANUAL (NSTM) | CHAPTER | NAVSEA CODE |
|---|---|---|---|---|
| ELECTRICAL | LONG BEACH | 223 | SUBMARINE STORAGE BATTERIES | 543 |
| | | 235 | ELECTRIC PROPULSION INSTALLATION | 543 |
| | | 300 | ELECTRIC PLANT GENERAL | 542 |
| | | 302 | ELECTRIC MOTORS & CONTROLLERS | 544 |
| | | 310 | ELECTRIC POWER GENERATORS AND CONVERSION EQUIPMENT | 544 |
| | | 320 | ELECTRIC POWER DISTRIBUTION | 542 |
| | | 330 | LIGHTING | 543 |
| | | 461 | ELECTRICAL MEASURING AND TEST INSTRUMENTS | 544 |
| | | 512 | FANS | 531 |
| E.LECTRONICS | PEARL | | | |
| WOODWORK | PUGET | | | |
| FABRIC WORK | MARE ISLAND | | | |
| SURFACE PRESER-VATION AND PAINTING | PEARL | | | |
| RIGGING | NORFOLK | 613 | RIGGING, WIRE & ROPES | 613 |
| ELECTROPLATING | CHARLESTON | | | |

# NEXT STEPS (CONT'D)

| | SHIPYARD RESPONSIBLE FOR MODULE TRAINING DEVELOPMENT | | NAVSEA TECHNICAL MANUAL (NSTM) CHAPTER | NAVSEA CODE |
|---|---|---|---|---|
| MACHINE SHOP MACHINIST | PHILADELPHIA | 551 | COMPRESSED AIR PLANTS | 533 |
| | | 554 | BLOWERS | 532 |
| | | 556 | HYDRAULIC EQUIPMENT POWER TRANSMISSION & CONTROL | 513 |
| | | 561 | SUBMARINE STEERING & DIVING SYSTEMS | 513 |
| | | 562 | SURFACE SHIP STEERING SYSTEM | 513 |
| | | 571 | WINCHES AND CAPSTANS | 514 |
| BOILER WORK | LONG BEACH | 221 | BOILERS | 522 |
| | | 254 | CONDENSERS HEAT EXCH. AND AIR REJECTORS | 522 |
| | | 531 | DISTILLING PLANTS | 522 |
| PIPE FITTING | MARE ISLAND | 505 | PIPING SYSTEMS | 532 |
| | | 533 | POTABLE WATER SYSTEMS | 533 |
| INSULATION | PHILADELPHIA | 635 | THERMAL INSULATION | 635 |
| AIR CONOITIONING ANO REFRIGERATION | PORTSMOUTH | 516 | REFRIGERATION SYSTEMS | 532 |
| ORDNANCE EDUIP. MECHANICAL | NOS LOUISVILLE | | | |

2. DESIGNATE OTHER SHIPYARDS FOR COGNIZANCE OVER OTHER SPECIFIC AREAS:

   SUPPLY ---

   PLANNING ---

   ESTIMATING ---

   SCHEDULING ---

   WORKLOADING ---

   PROGRESSING ---

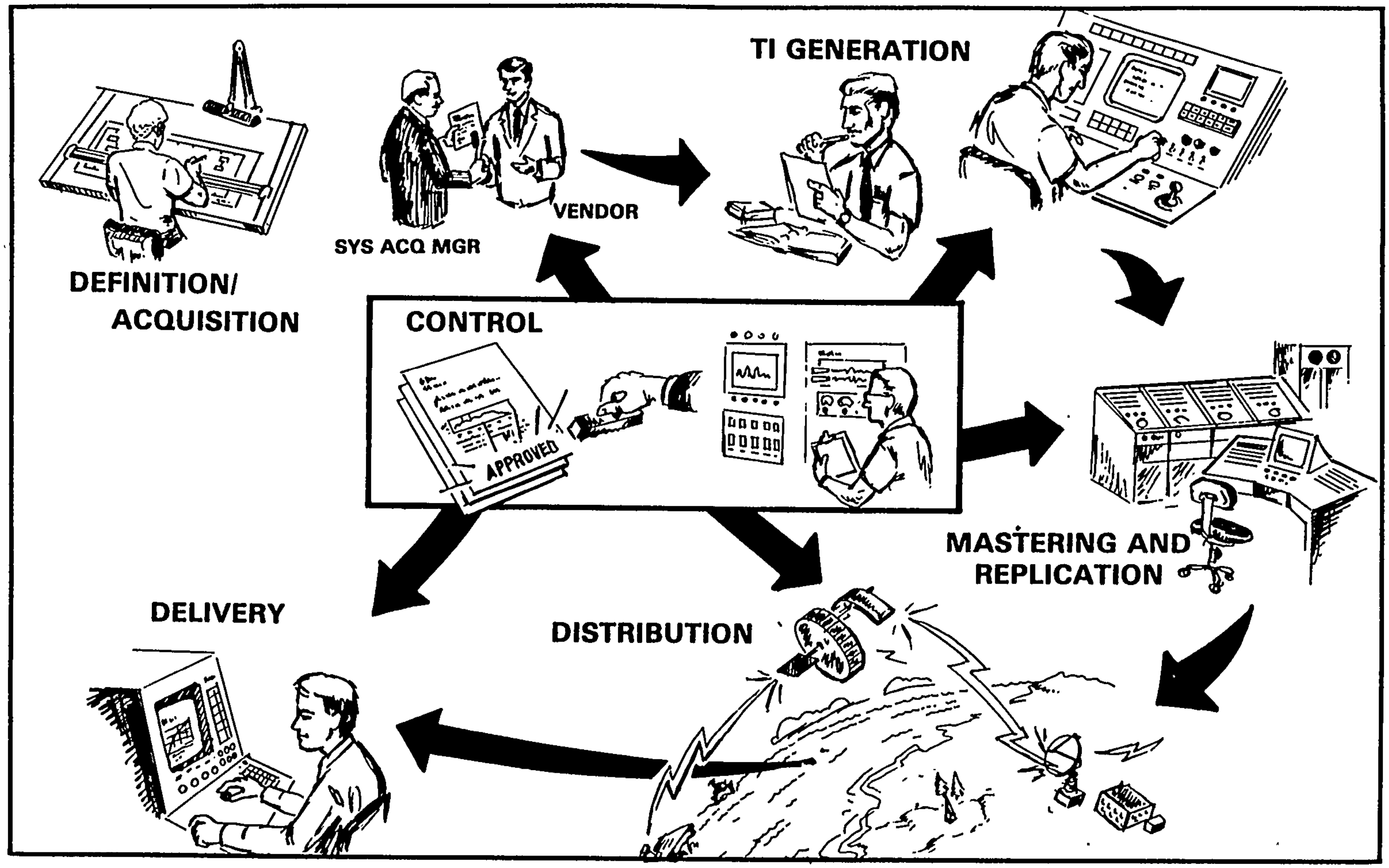
   TESTING ---

3. DETERMINE STANDARD FORMAT AND SPECIFICATION FOR PROCESSES INCLUDING IN PARTICULAR USEFULNESS BY ALL WORKERS, ADAPTABILITY TO WORD PROCESSING AND AUTOMATED DATA PROCESSING SYSTEMS, SIMPLICITY, UNIFORMITY, THE AVOIDANCE OF DUPLICATION AND INTEGRATION WITH OTHER SYSTEMS (MT; 3M, OA, NDE, ETC.).

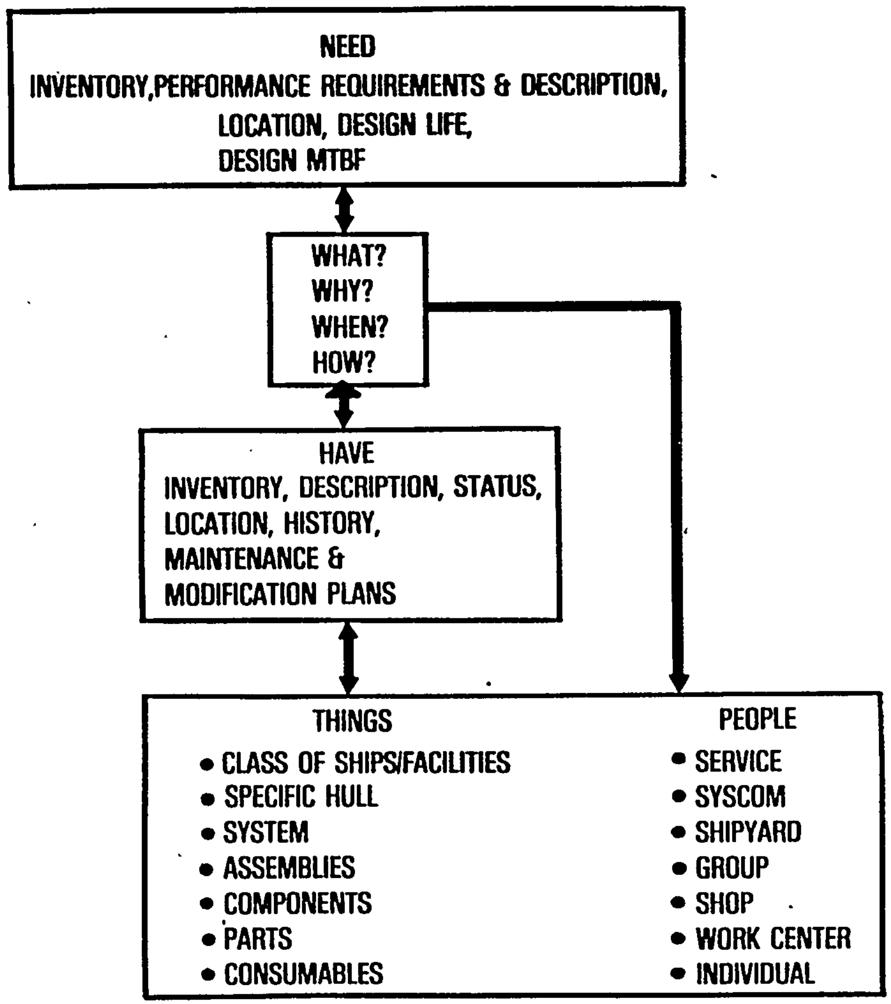
4. TRIAL RUN COMBINATION OF BEST FEATURES OF NTIPS, CATS, PROMPT, SKILLS TRAINING PROGRAM UTILIZING BEST AVAILABLE ADP SYSTEMS FOR REACHING CONCENSUS ON BEST SYSTEM.

5. UTILIZE TRADE SKILLS WORK SHOP: TO PROMULGATE AND REFINE SKILLS TRAINING AND STANDARD PROCESSES.

# 6. CONTINUE TO DEVELOP AN EVOLUTIONARY PLAN THAT REFINES THE FOLLOWING ASPECTS:



# 7. INTEGRATE INTO A TOTAL INFORMATION AND DECISION SUPPORT SYSTEM:



# THE FUNCTIONAL APPROACH TO PROBLEM SOLVING IN THE SHIPYARD ENVIRONMENT

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Mr. Scott has been with the Electric Boat Division of General Dynamics for the past 26 years. For the last 10 years he has been Chief of Engineering in the Operations Engineering Department. His functional responsibilities include an engineering support program to the shipyard (Operations Department) in two major areas: (1) A problem identification/resolution group, and (2) The Operations Departments Data Processing interface group. Since both groups are involved in all aspects of the shipyard and the shipyard organization, the day to day activities virtually span every aspect of the shipbuilding business. However, primary emphasis is directed at the manual and automated work control and information systems in direct support of the shipyard and the product.

Mr. Scott attended the University of Rhode Island. Prior to his current assignment, he held management positions in the Marine Engineering and Cost Engineering Departments.

Johan Collasius
Engineering Specialist
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Mr. Collasius has 10 years experience in the area of identifying problems, proposing solutions, and implementing solutions to manual and automated work control and information systems in direct support of the shipyard. His group has acted as the interface between system and end-users (shipyard trades) and the data systems service providing user definition for system data base requirements, output report design, detail logic design, and implementation plans.

Mr. Collasius has received a BS degree in industrial engineering from Southeastern Massachusetts University, a MBA degree with a concentration in operations research from the University of New Haven, and is currently enrolled in a Senior Professional Certificate program in computer science at the University of New Haven.

## I. SYNOPSIS

This discussion will cover a structured problem solving methodology as it is used in the Operations Department at the Electric Boat Division of General Dynamics. A brief overview will describe several successful applications of the problem solving methodology. To provide an understanding of the concepts, a brief description of the technique used will be given.

## II. GENERAL OVERVIEW

### A. Introduction

One of the newest buzz words in Navy-related shipbuilding today is Tech Mod or Technology Modernization. This program is a self assessement of your current "as is" operation and the development of a proposed or "will be" operation. The methodology we are about to describe provides the capability needed to perform the analysis for documenting the "as is" and developing the "will be".

Information flow, material flow, and work-in-process flow are the life's blood of every company, organization, or department. Your ability to understand it, and analyze the problems that occur in it, has a significant impact on its efficient operation. In many companies, the process of determining what went wrong, and what to do to fix it, is an informal effort. In most cases, it is left up to operating management and consensus opinion. In larger companies, it may become a management team or industrial engineering responsibility. Regardless, eventually someone in the organization is held accountable for resolving "the problem".

In the problem solving business, the "problem solvers" have a varying life span (see Figure 1-1). And, as the illustration shows, if you are consistently good, it can be quite long and happy If not, you often stumble your way through, in which case, it is usually very short and sometimes even fatal.

I'm sure that all of you have, at one time or another, witnessed or have been involved in one of those problems that that has been around for some time. One that others, or even yourself, might have broken your picks on. If so, maybe you will recognize some of the jobs we have successfully tackled over the years (see Figure 1-2):

- Refuse Disposal System
  - Classified materials - drawings - hotel trash
  - Meeting all Federal EPA regulations

- Pipe "Target" System
  - Requirements definition
  - WIP Status and Control
  - Work closeout

- Division-Wide Inventory System
  - All WIP material
  - All material installed on submarines

- Inventory Reconciliation System including:
  - Procedures and training
  - Project management responsibilities

- Division Hazardous Waste Control System
  - Meeting all Federal EPA regulations

- Structural Steel Weld Accountability System

- Pilot Machine Shop Work Control System
  - Work breakdown (product structure)
  - Part numbering
  - Data base load
  - User procedures and training
  - Project management
  - Turn-key to production
  - Fleet immediate needs (short term)
  - Capable of evolving to an MRP system (long term)

- Numerous Trade Work Center Analysis

These are representative of the kinds of problems that could be encountered in any shipyard.

The point is that these problems were resolved and many others, using a very easily learned analysis technique. And, most importantly, we consistently do these types of jobs without falling into the usual pattern of solving the wrong problem right, one or more times, before finally stumbling onto the real problem and solution.

In fact, I tell my engineers that this is my biggest fear -- the fear of solving the wrong problem right. Let me give you one example because I think it illustrates what can, and often does, happen:

- Take the Refuse System previously mentioned - (see Figure 1-3):

  Back a few years ago, EB was having problems with their incinerator - it belched black smoke. It eventually got to the point where the EPA was threatening a $25,000 fine.

One of our sister engineering groups had already been tasked to solve the problem. In fact, they spent several months and nearly $100,000 trying to stop that incinerator from belching black smoke. Failing to do so; and after some further EPA stimulation, we were asked to go "take a look" at the "Incinerator Problem". Our approach was considerably different. We documented and analyzed the entire refuse disposal system at EB and eventually included our facility at Quonset Point, Rhode Island. Without going into all the details, our analysis included contract requirements, ASPER regulations, Nuclear Regulatory requirements, trash classification [how much of what kind from where]., facilities, and equipment. What we found was much more than an incinerator problem. Our solution was to, get rid of the incinerator and install a large scale sheer type shredder, coupled with an approved landfill operation. We wrote the specs for the shredder, monitored manufacturing of it, tested it, did the facility layout, obtained spec changes in our contracts, changed operating procedures, etc. And, that is how we dispose of trash today. And, there is no black smoke, no threatening EPA fine fines, and the refuse disposal system works just

I think that you can see that much more obvious solutions could have been developed:

- Perhaps eventually the incinerators could have been made to work, or maybe a more modern, higher temperature pressurized incinerator would have done the job -- maybe not.

Regardless, the point is that the final solution was not, and seldom is, the obvious! Actually, more often than not, the obvious is simply a sympton - seldom the cause. Permanent solutions are almost always the result of in-depth analysis.

## III. OYERVIEW - ANALYSIS METHODOLOGY

### A. Introduction

Essentially, the message we hope to impart here today is an understanding of the problem solving methodology or technique we use to consistently solve the right problem right! An easily learned technique whose basis is structured after a Honeywell education course called BISAD, modified to work for use in our environment, which can be modified and learned by you and applied equally as well in your environment. However, the intent of this presentation is not to taut Honeywell's technique, it is to illustrate that a structured, disciplined, functional analytical approach, will yield consistent successful results.

## B. The BISAD (Business Information Systems Analysis and Design) Methodology

BISAD, as taught by Honeywell, covers two fundamental areas: (1) the Analysis Process; and (2) the process of Project Management. The discrete relationship between the two is that Project Management controls (manages) the implementation of the results of the analysis; in short, it gets the job done.

Briefly, described, the analysis methodology is a structured approach used to train computer systems people. When I say structured, I mean it is a defined step-by-step technique that proceeds from an interview phase called Background Analysis, to Functional Analysis, to Functional Design, to System Design, to the development of an implementation plan. A key element to the successful application of this methodology, is that it requires religious adherence to the technique - i.e., you do it by the book!

Project Management is tied directly to analysis because the ultimate success of the analysis can only be realized if and when full implementation takes place. Most importantly, it gives the project manager the "tool" he needs to control and status implementation.

## C. Methodology Overview

Conceptually, the BISAD Analysis and Project Control technique is illustrated as shown here (Figure 2-l). The purpose of this overview being to familiarize you with each phase of the analysis, and the terms used. What is illustrated here is that as a result of the background analysis interviews, several analytical steps are taken. First, a Function Activity Chart is developed. This is the identification of the activities performed and a grouping of the common or similar activities into what is called a function. For example, an Inventory Control function might consist of a grouping of activities called: scheduling, planning, inventory adjustments, purchasing.

The Function Activity Chart is then further developed in the form of a Total Information Interface Diagram whose acronym is called a "TIID". This diagram identifies the generic information that must flow between each function (inputs and outputs) in order for it to exist. For example, one input into the Inventory Control function might be material requirements from the Production Control Department; while the output would be the release of a purchase order. So, in reality, you have created a defined, illustrated picture of the problem, the generic information, and how it flows, including its interfaces.

This phase is followed by a further breakdown of the information identified in both the Function Activity Chart and the Total Information Interface Diagram (TIID). The analysis now takes the form of a Functional Information Interface Diagram or (FIID).. As shown by the illustration, a FIID is an illustrated breakdown of each function. It identifies the information flow (inputs and outputs) in terms of the documents themselves. For example, in the case of the Inventory Control function, you might find the purchase order is now called a Delivery Request, and so on. FIID's are developed for each function, thereby, defining in detail the information flow in and out of each function as it exists.

The Detail System Design phase is essentially a combining of the FIID's into one defined illustrated diagram that reflects the total proposed system, incorporating all. changes made to the existing system.

Lastly, all of the activities required to achieve implementation are identified and then sequenced in a modified PERT type diagram. This then becomes the Project Manager's control and status mechanism in the form of an implementation plan.

Remember these basic steps of (Figure 2-2):

- Background Analysis
- Function Activity Chart
- Total Information Interface Diagram (TIID),
- Functional Information Interface Diagram (FIID)
- Detail System Design
- Project Implementation Plan

## IV. PIPE HANGER PROBLEM ANALYSIS MODIFIED; BISAD; METHODOLOGY

The following will illustrate how the modified version was used to solve an actual problem at Electric Boat Division: identifying and controlling piping hangers to support both the installation and tests of piping systems.

A few months ago, Pipe Shop Management requested that a system be developed for identifying the availability and controlling installation of piping hangers. The first step was to document the way they were currently operating and to identify the operating problems. This step is a more structured flowcharting requirement than the background analysis approach in BISAD. As part of the background analysis interviews with operating management, we developed a Function/Activity Chart depicting the existing method of operating
You can see, it lists the functions required by the

the system down the left-hand side and the activities across horizontally. For example, the Central Trade Planning function consists of four activities: work scope definition, installation planning, design change evaluation, and closeout evaluation.

The next step was to take the information that was gathered and the Function/Activity Chart and develop an existing system - Total Information Interface Diagram or TIID (Figure 3-Z). Each of the functions identified in the Function/Activity Chart became a box on the TIID and each line between the boxes showed a type of information flow. This provided us with an overview of how all of the functions involved with piping hangers interacted with each other.

The next step was to take each of the functions on the TIID and Function/Activity Chart and develop a Functional Information Interface Diagram or FIID for it (Figure 3-3). Each of the activities identified on the Function/Activity Chart becomes a processing block on the FIID and the lines and documents flowing between activities provide a graphic illustration of what goes on within each function. For example, there were four activities on the Function/Activity Chart for the Central Trade Planning function and there are four blocks on the Central Trade Planning FIID. It identifies the documents used to transfer information from activity to activity and shows the interfaces that each activity has with other functions (those that are shown in dotted lines). These are the tools that we used to analyze the information flow, activities, and computer files to identify operating problems, additional information requirements, and redundant activities.

While performing the documentation, developing the TIID, and the FIID's, we add another enhancement to the BISAD technique - the Formal Problem Log - (Figure 3-4). The problem log is utilized in each phase of the analysis of the existing system and during design and implementation of the proposed system - (Figure 3-5).

We start maintaining the log during our initial interviews with Operating Management and religiously maintain it throughout the study. This gives us the problem baseline which our proposals must resolve. If all problems are not resolved to everyone's satisfaction, then it is back to the drawing board.. The problem log is also a valuable tool to aid us in developing both short-term and long-term solutions to problems. As you all know, many times there simply is not enough time to develop and install the final solution, and an interim or short-term step that dovetails with the long-term solution is implemented.

In short, if you want to be consistently (and I underscore consistently) effective, you have to have a reliable technique to identify the real problems and then, where needed, be able to develop short, as well as long-term solutions. The problem log along with our modified BISAD functional analysis technique are the tools we have used to accomplish this for the past 8 years.

What we found in the hanger system were several operating problems which were impacting our ability to correctly identify installation requirements, availability, and status of those requirements in relation to a specific test schedule. Once we had the problems isolated, our proposal included the solutions which were designed and presented in the same format - TIID's and FIID's (Figure 3-6) where the changes were highlighted.

The proposed hanger system included development and load of pipe hanger installation requirements to a data base. These requirements were in turn identified to test sections and statused for material availability and installation completeness. Using the computer data base, we then sorted the requirements file and obtained the information in any format needed.

A further enhancement will be to identify and load the area of the ship that the hanger is located in, so that we will be able to obtain requirements and installation status by area of the ship as well.

Once approved for implementation, the FIID's formed the basis for the detail level flowcharts (Figure 3-7) which, when literally translated, became the department operating procedures. The detail level flowchart shows "how" the proposed system works. It shows what decisions have to be made and the actions that take place to make the system work.

The next step was implementation of the new system. To control the implementation, we utilized the Project Control Methodology. We identified the individual activities with dependencies, estimated the span times, assigned responsibilities, and determined resources required. These activities were then drawn into a simplified PERT type chart (Figure 3-8) implementation plan. This implementation plan then became our control mechanism (on one piece of paper) identifying the specific activities that were required, the sequence they had to take place in, the schedule and identified who was responsible for accomplishing the activity.

As each implementation activity is completed, the appropriate "bubble" is colored in so that we can see, at a glance, the status of implementation (Figure 3-9). The implementation chart also highlights those individuals on schedule and more importantly, specifically who is holding up implementation. Likewise, it identifies to the project manager where he has to allocate more resources and do the pushing to get implementation back on track and keep it there! It sounds simplistic because it is - and most importantly, it works!.

That was a brief overview of how a modified version of BISAD is applied at the Electric Boat Division. I might note that all of the engineers in our group have had the formal BISAD training taught by Honeywell. As you can see, the technique can be learned and applied by anyone, to identify and solve problems in essentially any type of business environment including shipyards.

## V. SUMMARY

The summary is short and to the point! (Figure 4-1) The modified BISAD systems analysis methodology is the analysis methodology used. In short, it includes a formal documentation of the existing system in the form of a Function Activity Chart, a Total Information Diagram (TIID), and then in a lower level of detail, a Function Information Diagram (FIID). Throughout each step, a formal problem log is developed and maintained. The solution or proposal is then simply a re-drawing of the Functional Information Diagram to incorporate the change necessary to solve the problems. This then becomes the Detail System Design. The translation of these documents into words becomes the operating procedure. They also serve as the training guides.

Every analysis includes a proposed project implementation plan with defined, sequenced activities, assigned responsibilities, the resources, and scheduled spantime to accomplish it. The only other key ingredient is a religious adherence to the methodology. Everyone uses it; and everyone uses it the same way - by the book!

Simply stated, it is an easy-to-learn, effective, standard means for doing problem analysis, systems analysis, and system design, while the project management plan ensures that the job gets implemented.

FIGURE 1-1

**PROBLEM SOLVERS' LIFE SPAN?**

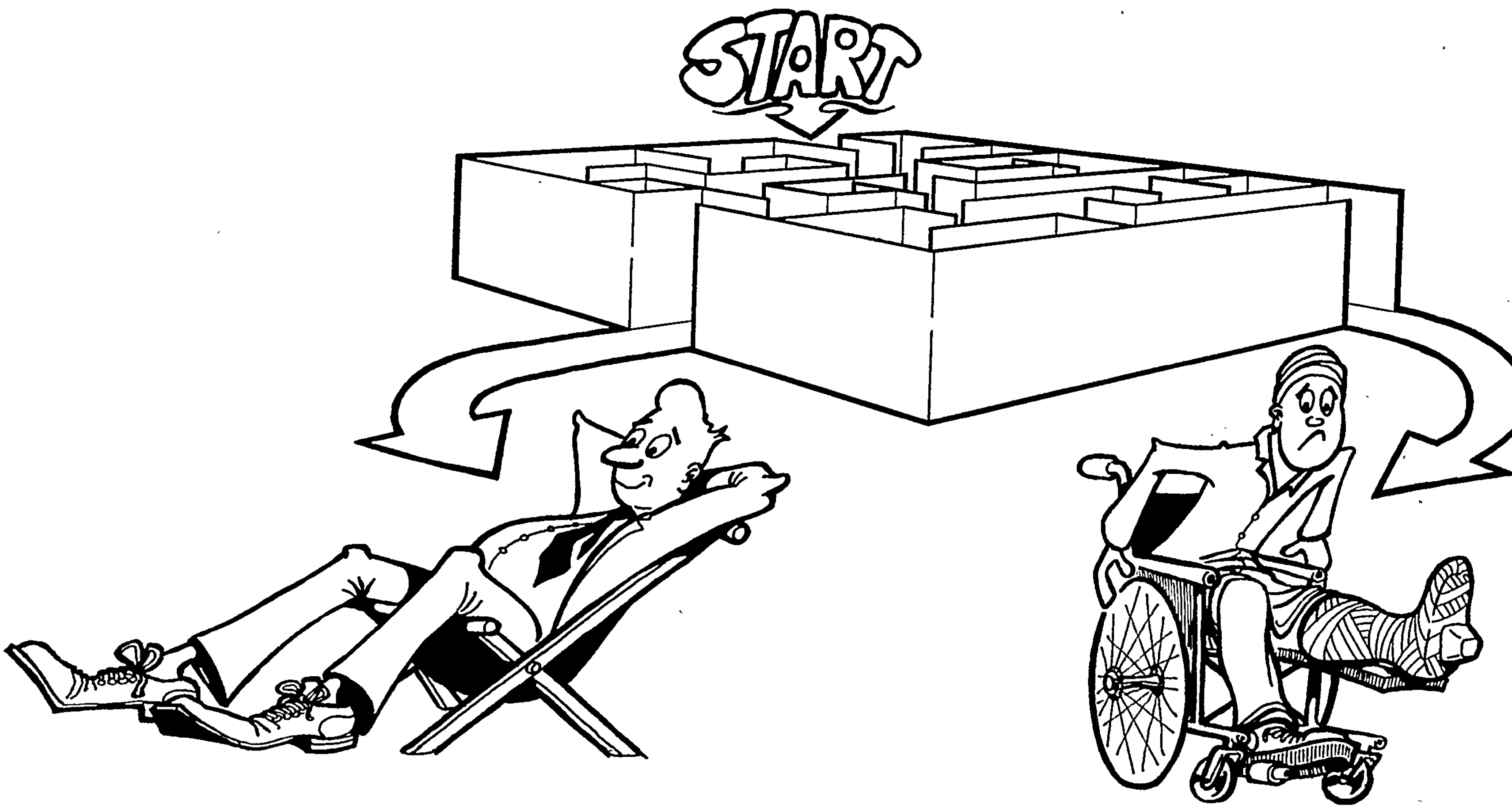


FIGURE 1-2

SAMPLE PROBLEM LIST

- REFUSE DISPOSAL SYSTEM
- PIPE SYSTEM FINAL CLOSURE “TARGET”
- DIVISION-WIDE INVENTORY SYSTEM
- INVENTORY RECONCILIATION SYSTEM
- HAZARDOUS WASTE CONTROL SYSTEM
- STRUCTURAL STEEL WELD ACCOUNTABILITY SYSTEM
- PILOT MACHINE SHOP WORK CONTROL SYSTEM
- TRADE WORK CENTER ANALYSES

FIGURE I-3

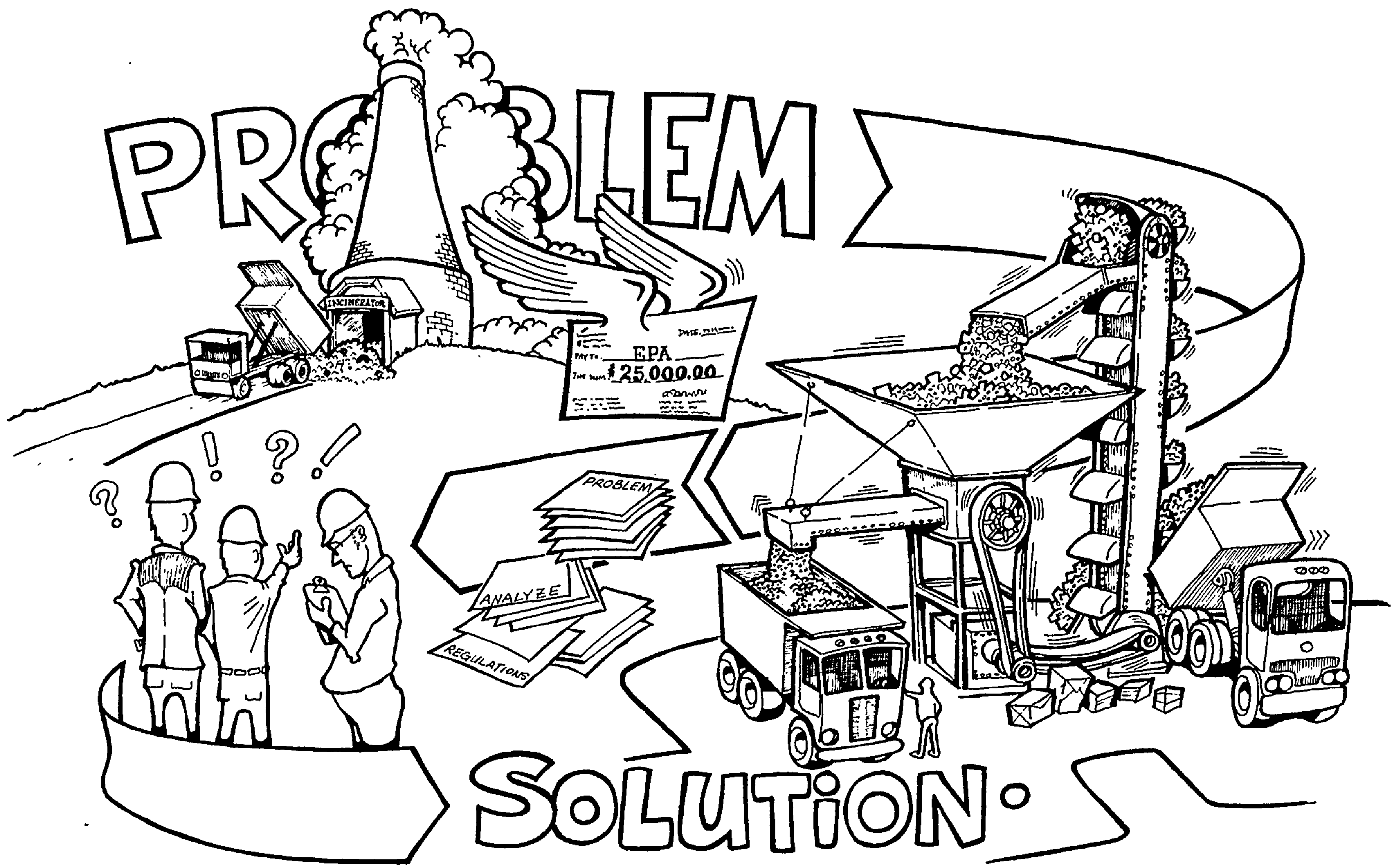

PROBLEM
INCINERATOR
DATE
PAY TO
EPA
$25,000.00
PROBLEM
ANALYZE
REGULATIONS
SOLUTION

FIGURE 2-1

# BISAD CONCEPTS

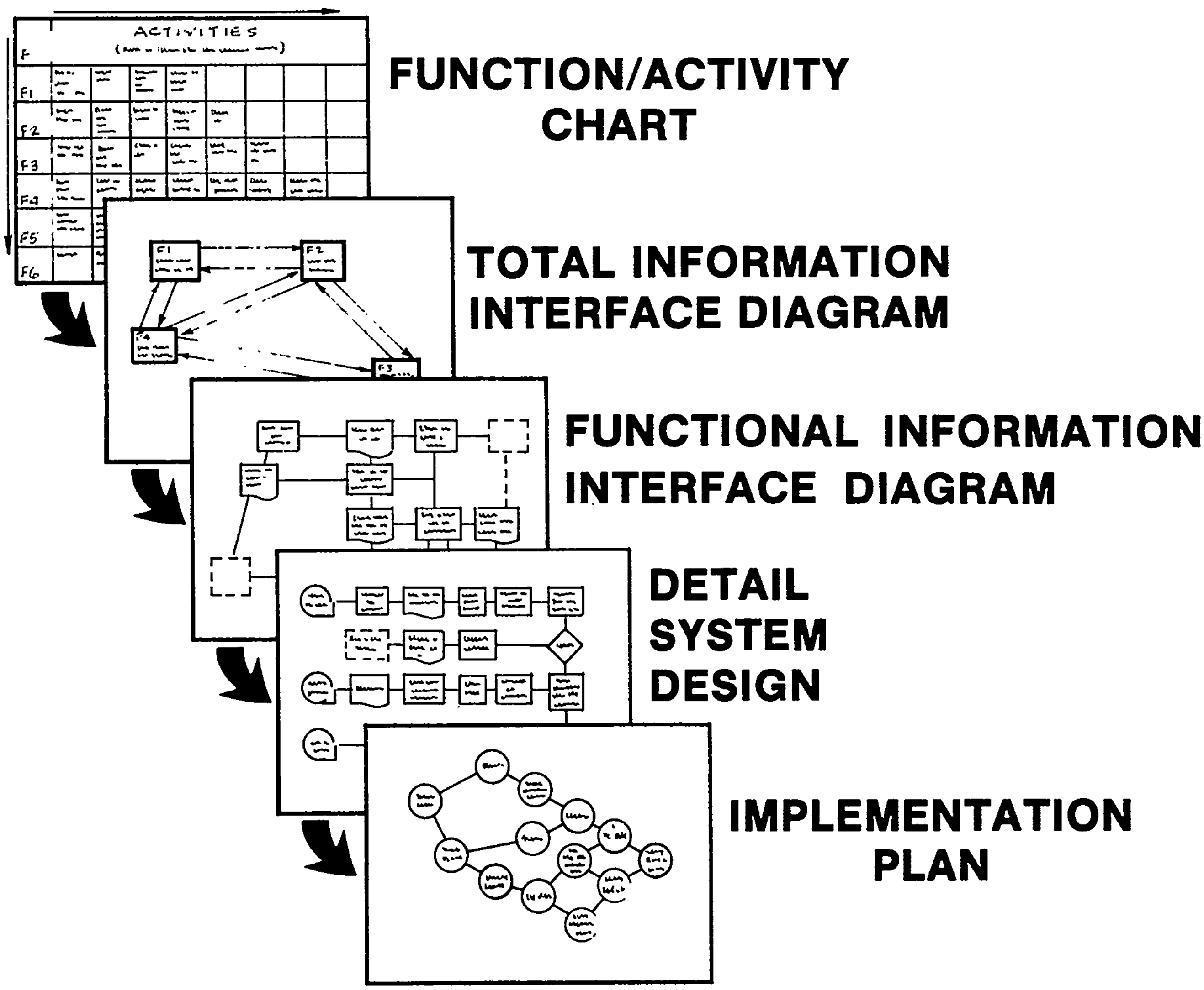


FIGURE2-2

# BISAD ANALYSIS STEPS

• BACKGROUND ANALYSIS

l FUNCTION ACTIVITY CHART

l TOTAL INFORMATION INTERFACE DIAGRAM - TIID

l FUNCTIONAL INFORMATION INTERFACE DIAGRAM - F I I D

• DETAIL SYSTEM DESIGN

• PROJECT IMPLEMENTATION PLAN

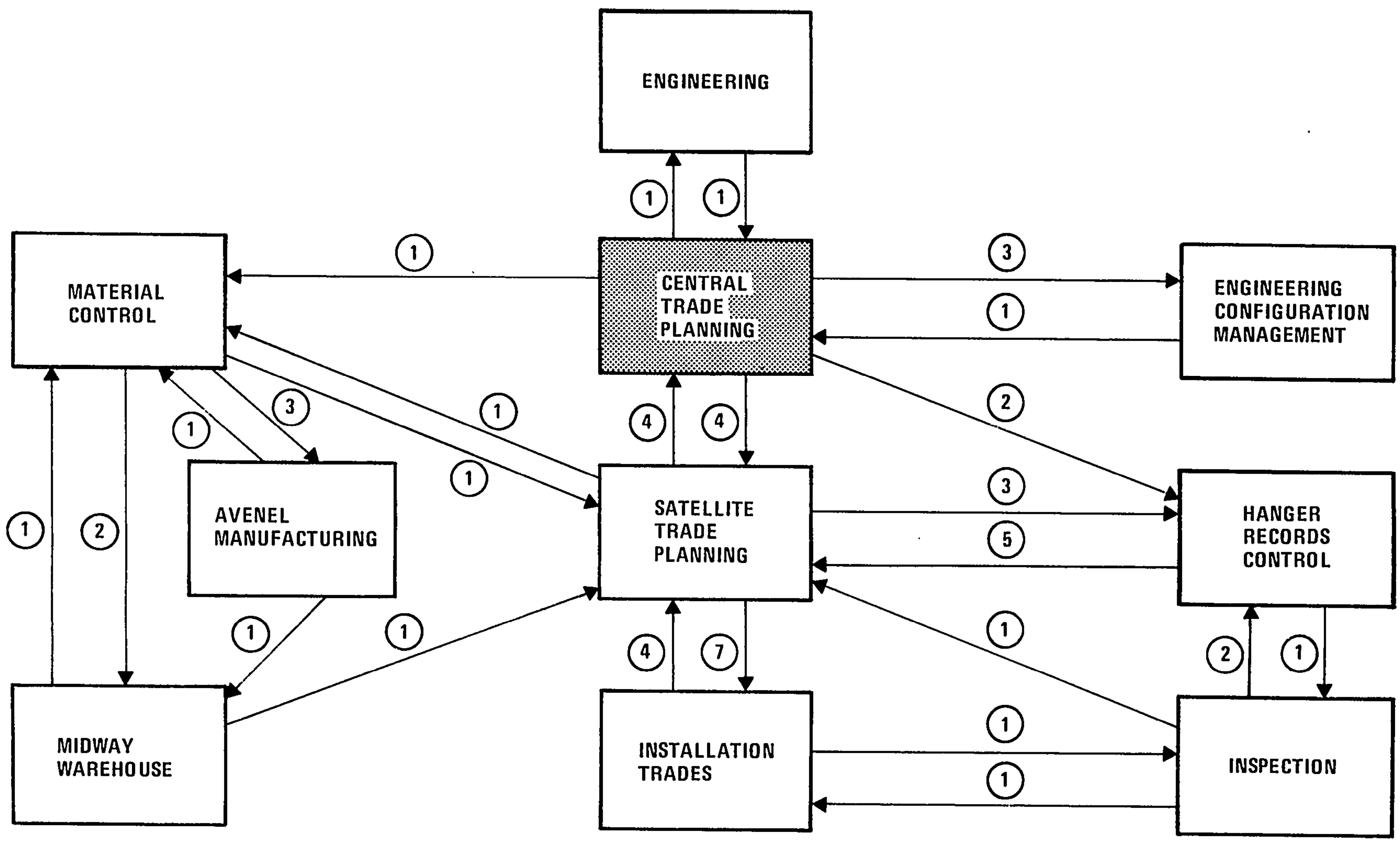
FIGURE 3-1

# HANGER SYSTEM FUNCTION/ACTIVITY CHART - EXISTING SYSTEM

| FUNCTIONS ↓ | ACTIVITIES → | | | | | |
|---|---|---|---|---|---|---|
| INVENTORY CONTROL | PRODUCTION SCHEDULING | PRODUCTION PLANNING | INVENTORY CONTROLS ADJUSTMENT | INVENTORY ADJUSTMENT | PURCHASING | |
| MANUFACTURING (AVENEL) | MFG. PLANNING | MANUFACTURE | SHIPPING | | | |
| MIDWAY WAREHOUSE | RECEIVING | STOCKING | PICKING | STAGING | SHIPPING | PHYSICAL INVENTORY |
| CENTRAL TRADE PLANNING | WORK SCOPE DEFINITION | INSTALLATION PLANNING | DESIGN CHANGE EVALUATION | CLOSEOUT EVALUATION | | |
| SATELLITE PLANNING | MATERIAL ORDERING | MATERIAL RECEIVING | INSTALLATION PLANNING | CLOSEOUT INITIATION | | |
| | | | | | | |

FIGURE 3-2

## TOTAL INFORMATION INTERFACE DIAGRAM (TIID)



## FIGURE 3-3

**FUNCTIONAL ANALYSIS – FIID**

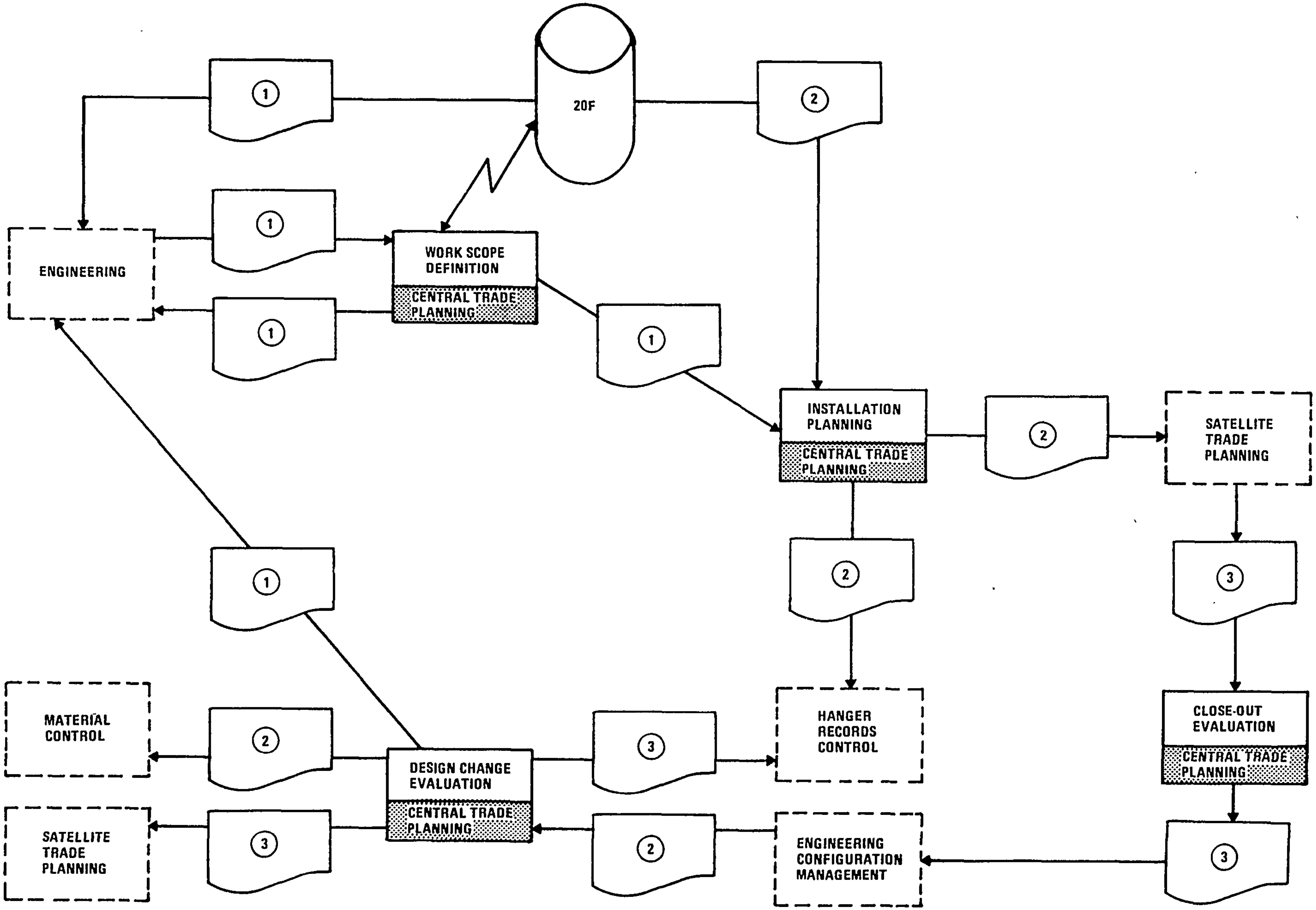


FIGURE 3-4

# PROBLEM LOG

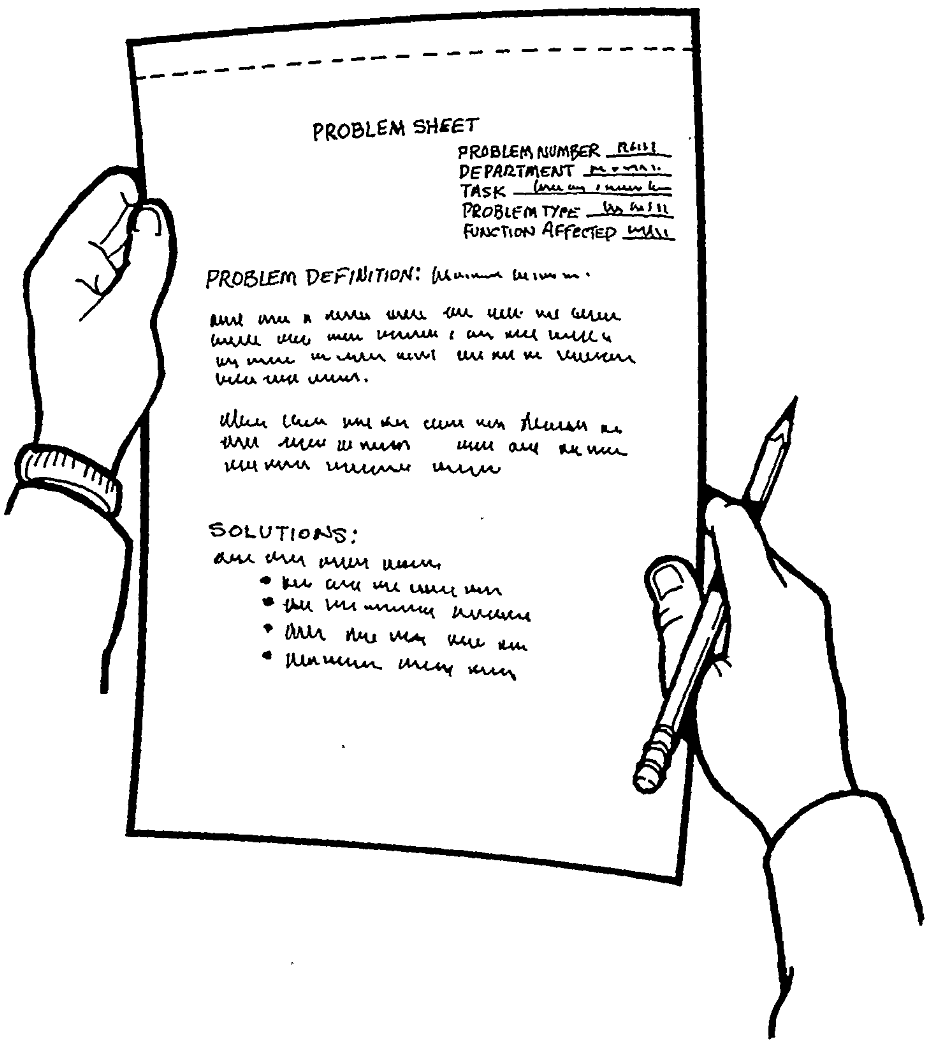
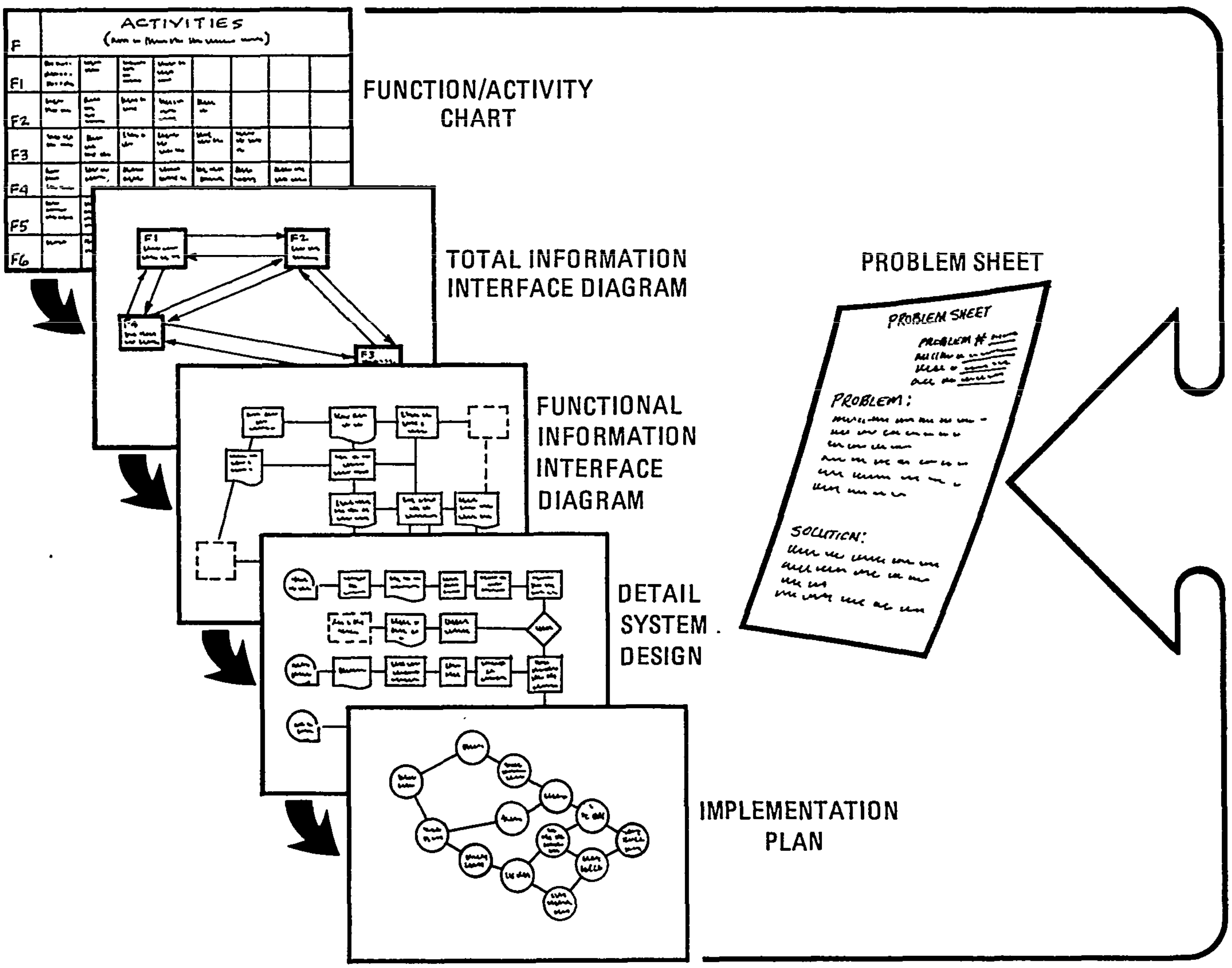


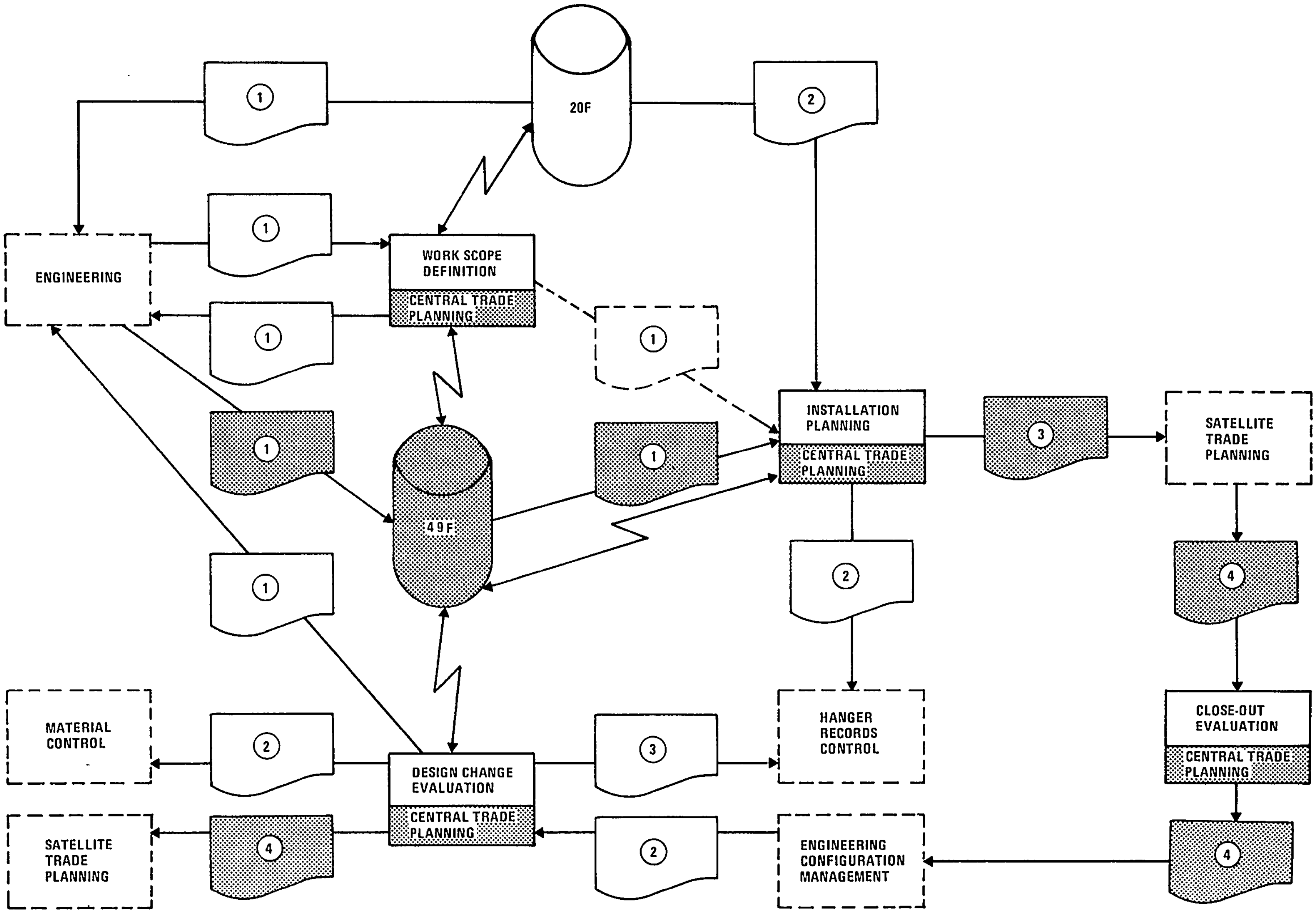
FIGURE 3-5

# BISAD CONCEPTS WITH MODIFICATION



# FIGURE 3-6

## SYSTEM PROTOTYPE - FIID



# FIGURE 3-7

## WORKING SYSTEM DESIGN

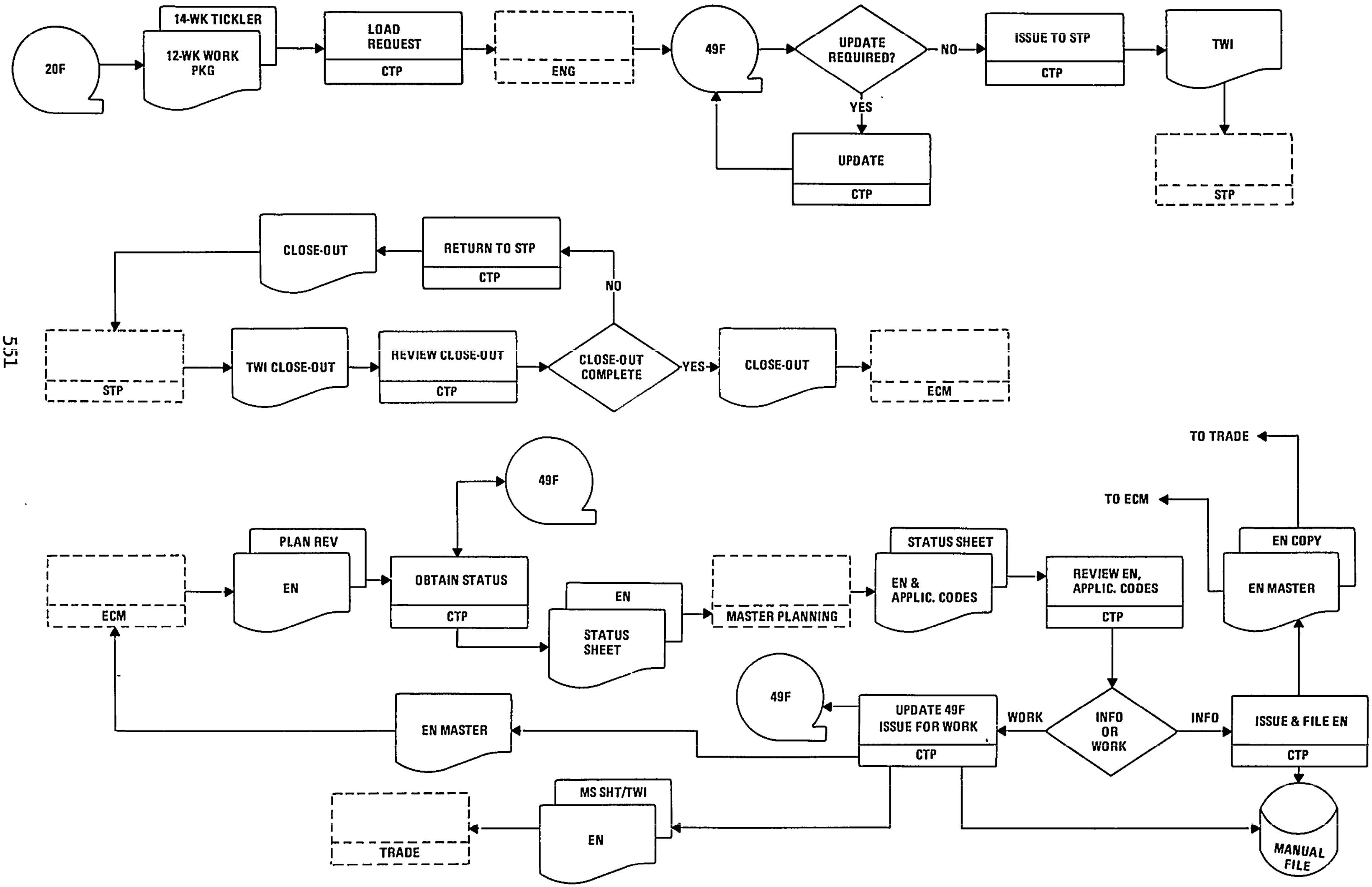


FIGURE 3-8

# IMPLEMENTATION PLAN

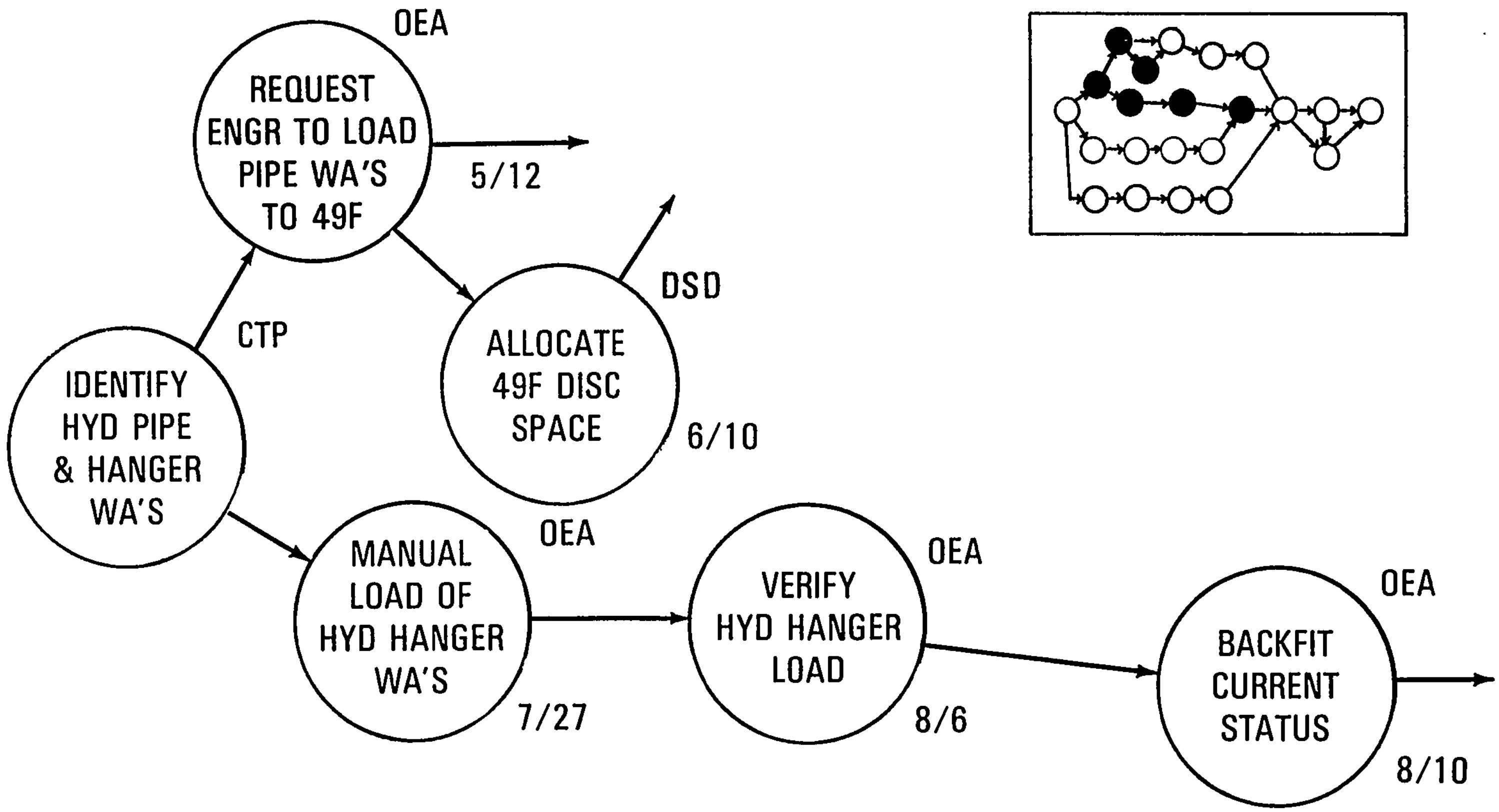


FIGURE 3-9

# STATUSED OPERATIONAL IMPLEMENTATION PLAN

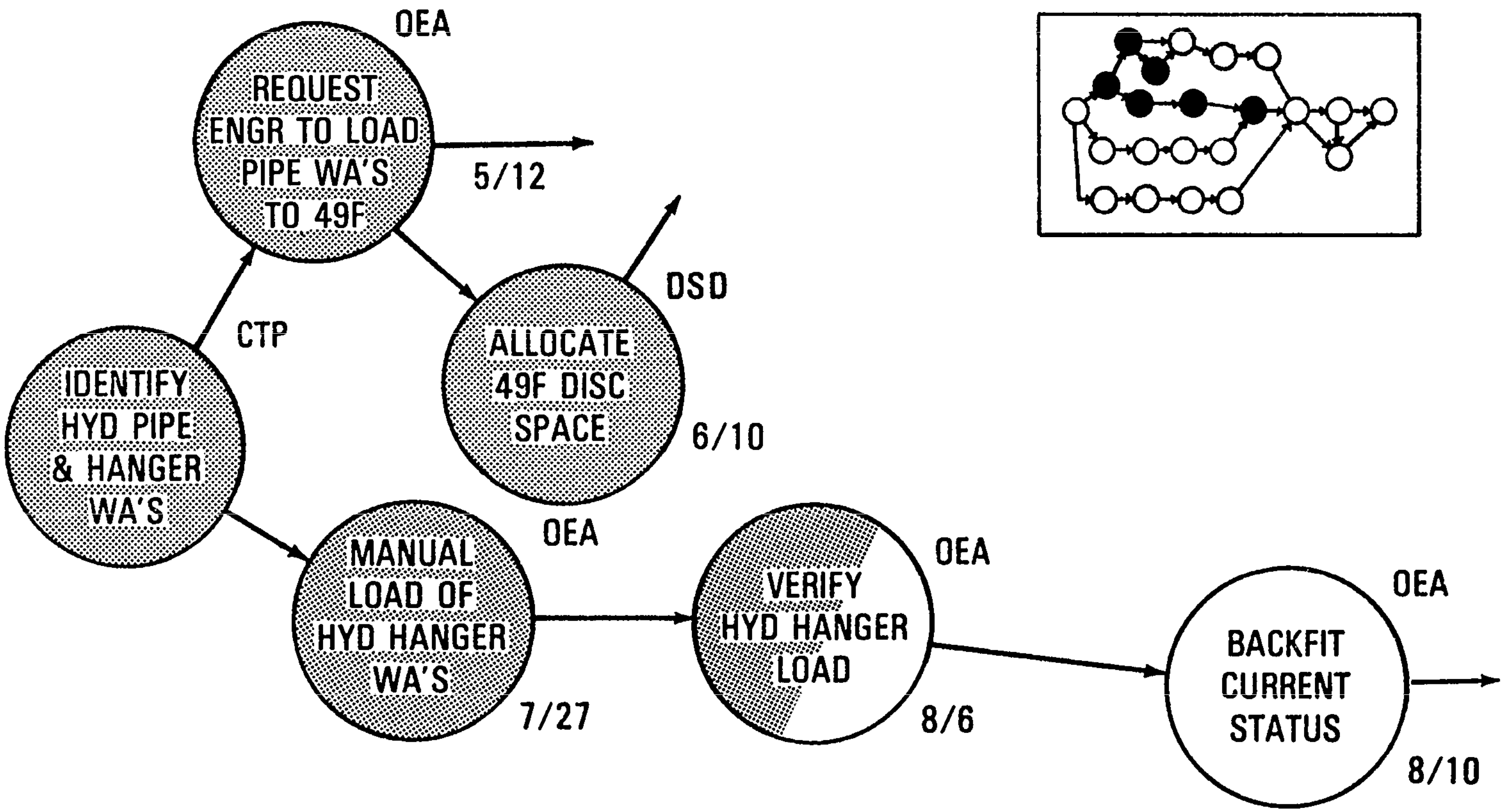
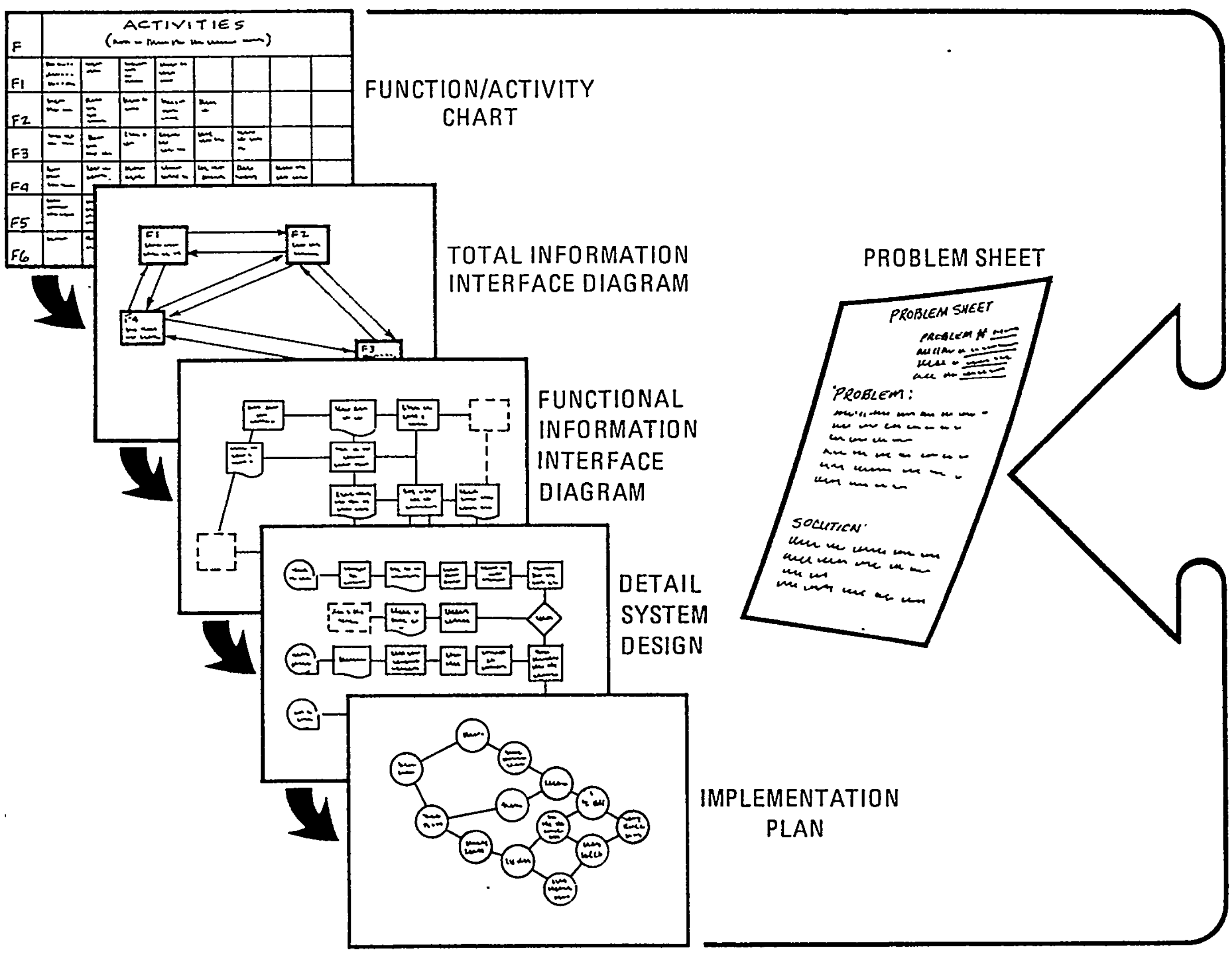


FIGURE 4-I

# PROBLEM SOLVING OVERVIEW



# HUMAN PERFORMANCE ENGINEERING:
# A TECHNOLOGY FOR DEVELOPING THE HUMAN RESOURCE

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Dr. Anderson had his doctoral training in experimental psychology in a joint program at the Universities of Portland and Oregon Medical School. He had off-and-on postdoctoral training in Department of Psychiatry, Stanford Medical Center and Universities of Southern California and Minnesota. He is author of approximately 70 scientific publications, two textbooks, 80 scientific presentations, and several hundred management addresses. His basic research interests center in areas of learning and motivation. Applied research interests concern applications of technology of human performance engineering in organizational settings.

## ABSTRACT

Human performance engineering is a behavioral technology that rests on the proposition that increases or decreases in productivity always are the byproduct of human action. The key to increased productivity thus begins with location of those actions that must be changed. This is followed by the introduction of variables known to be effective in bringing about alterations in human behavior. By this approach, managers are envisioned as major sources of such variables. Increasing productivity thus is tantamount to engaging managers in an appropriate application of these causal agents. Following a careful enumeration of the procedures and results of this approach in a manufacturing setting, a detailed proposal outlining, application to the shipbuilding setting is presented.

## INTRODUCTION

Last year in my invited address to you, I listed many of the factors that likely have contributed to the current productivity slowdown in the U. S. This listing underscored that this slowdown is multi-determined, and suggested that certain of these determinants more readily could be addressed by each of us than others. For example, the resource-draining influence of federal regulations that seemingly has increased logarithmically in number since the middle 1960s probably only slowly can be reversed, and then not without involvement of complex political "machinery." Moreover, there is little that can be done about the loss of work excellence formerly supplied by the now-ended migration of farm workers into our labor marketplaces. Further, the enormously complex problems and uniformly nonbeneficial influences wrought by inflation, combined with near-unchecked federal spending, are not easily addressed by any single industry, let alone single groups and/or individuals. Indeed, current high interest rates coupled with this spiralling inflation appear to have prompted many of our organizations to become mini-banks rather than to fulfill their original committments to manufacturing, service, and sales activities. These current economic conditions thus reinforce nonproductivity and corresponding unemployment that, in turn, beget further of these ailments in a sort of endless vicious circle. Noteworthy also has been the continued influx of the young and inexperienced as well as an increased proportion of female workers, estimated by some to have contributed 18% of the current slowdown in productivity, again exemplifying difficulties that probably only gradually and complexly can be surmounted. Finally, sociologists have expressed concern about the counter-productive pressures within organizations toward upward mobility within management heirarchies. The contention here is that such pressures reinforce unusual conservativeness and a tendency tendency holding the status quo rather than fostering the bold, creative, imaginative, and innovative actions by young and/or aspiring managers that are needed to deal with productivity problems.

while many of these ingredients thus likely will require remedies that each of us as individuals only indirectly can influence, I noted last year certain other problems that impact productivity that each of us more clearly and directly could address. In part, some of these "addressable" problems are highlighted by the results of polls that have been conducted over the past 15 years, the exact period that characterizes the time frame of the current slowdown. Pollsters tell of pervasive changes in the attitudes, work ethics, committments, and of the declining respect that our workforce

currently holds for its employers. For example, polls show that about 70% of the workforce "trusted" their employers at the end of the 196Os, but that less than 30% have a similar trust today. Further, although well over 65% during the late 1960s reported that they "respected" their supervisors, most now apparently feel that they openly can disagree with their managers. Finally, well over 70% of our workforce in 1968 conceded that individual effort and hard work paid off, but by the mid-1970s the percentage fell to about 30% that expressed the belief that their individual efforts were noticed and rewarded. In addition, pollsters tell us that rather than quit work, a significant percentage of our workforce has learned to withdraw in other ways. In effect, efforts to camouflague sagging work habits seem to have increased markedly, a significant proportion of our workers now "push" the rules, and often show indifference if not outright hostility when confronted with these seeming inproprieties. These findings prepare us for understanding the polls on the subject of job satisfaction. The evidence is unanimous that satisfaction in work is near an all-time low, regardless of vocation, position, sex, age, and so forth. And, for those that believe that job satisfaction and productivity are directly related, this indeed is an ominous sign.

Other factors impact against full committment to increased work by our human resource as well. Pollsters speak of a precipitous rise in middle-aged crises. More divorces, more problems with children, **more** alcoholism and related addictions, and less self-esteem have conspired to distract our middle-aged work population away from productive output. we also are informed that the changing social security and other laws have increased the proportion of older workers that populate the workforce. If the stereotype is correct that older workers are less productive, then we have yet another human-resource problem that must be addressed.

An interesting recent study regarding our human resource compared the number of minutes actually worked per hour of pay by the average U. S. and Japanese worker. Allowing for the possibility of an indirect calculation procedure, these data are nonetheless to be regarded with considerable concern. The average Japanese worker was found to return 58+ minutes of work for every hour of pay. In contrast, the averages U. S. worker purportedly yields only 45 minutes of work per hour. While, a 130minute difference may seem relatively trivial when considered for a single hour, when summed over a typical 8-hour work day, it is anything but insignificant. The differential adds up to 104 minutes, or almost two full hours per day of lost labor!1 And, when totaled for an 40-hour work week, the result is aver a full day's work that is paid for but not received Now, while caution doubtlessly is adviseable in the interpretation of this statistic, certainly this difference across countries in work output must account for some of the reason why many U. s. industries have serious survival problems at present. Indeed, consider how a single day's work could help one of the manufacturering concerns wherein **we** now are installing a Human-Performance-Engineering (HPE) program to increase work output. This company makes, among other things, a product that sells for

slightly over **$20.00** per 1000 pieces. The exact duplicate (identical quality) manufactured in Taiwan sells for slightly over $9.00 per 1000, a price for the finished product that is well below the cost of the steel to our U. S. company. If we could obtain 13 more minutes per hour of work from each plant employee in this organization, we would be able to produce the same product for about $6500.00 less per week, or about a 22% savings. **Now,** while $16.00 per 1000 still is a long way from the $9.00 amount for the Taiwan product, can there be any doubt that such is a step in the right direction. And, when coupled with better and quicker service, greater product versatility, and so forth, there should be little question that this U. S. company could be more competitive than they presently are! Please note that while only in the beginning phases of this application, we already ***are*** over a third of the way to our goal of a 22% increase in work output.

Pollsters contend that the major factor needed for addressing most of the current problems with our human resource is that of a..."management style that managers have not learned yet." Of course, this invective suggests that we have knowledge of such a "style," that there is only one and not several styles and, finally, that managers can master and implement "it." Last year, I proposed that such a "style" indeed was available, and presented data on "its" effectiveness from three markedly different applications to show that managers with different backgrounds, experiences, persuasions, sexes, ages, temperaments, and so forth could indeed not only learn "it," but also maintain its implementation for prolonged periods. One of these applications was within a large metropolitan hotel that, in order to reverse a sagging reputation and increase clientele, required massive deep cleaning of virtually the entire property. while I summarized only that portion of our program that involved the maids and the room areas, we now have published our data in connection with cleaning and, then maintaining the public areas as well (including all lobbies, hallways, seven restaurants, and the back of the house), and with bellmen in order to increase both the quality and quantity of customer service. These programmatic applications since have been extended to other properties, including hotels in Scottsdale, Az., Chicago, Ill., Detroit, Mi., Danvers, Nass., Nashville, Tn. and, most recently, Rochester, Mn. Different managers, employee population, property configurations, and program applications were involved across these sites, yet all have been remarkably and perduringly successful in increasing both the quality and quantity of service, cleaning, food preparation, and so forth in each instance.

Time did not permit detailed coverage of program application in a sales setting (real estate) last year and, unfortunately, this program also was not well summarized in my 1981 IREAPS paper. For those wishing a more detailed summary, please write or consult the upcoming November issue of TEE JOURNAL OF ORGANIZATIONAL BEHAVIOR MANAGEMENT (1982). Again, increased productivity from the salesforce, indisputably attributable to the program ingredients that I outlined last year, resulted in a remarkable increase in profitability and an change in company competitiveness from seventh

for proportion of business in the area to first by a wide margin. Moreover, this was accomplished with managers and a workforce that were quite different from those involved in our hotel programs.

In addition, please recall the rather extensive program application within a furniture manufacturing organization wherein was displayed, among other things, systematic and lasting changes in worker efficiency due to program ingredients on a department-by-department basis (well summarized in the 1981 IREAPS PROCEEDINGS). Overall efficiency increases in some departments exceeded 15%, and no department failed to show significant gains on this measure of impressive magnitude. These program-produced changes were displayed as of the late Spring, 1981, and were the culmination of efforts initiated in late 1977. To achieve the reported outcomes, managers of very different backgrounds, ages, training and experience, and of both sexes were involved at all organizational levels. And, the same individual differences characterized the work population as well. Also noted in last year's presentation were extensions of program ingredients to the white-collar workforce in the corporate offices of this company, and to the delivery division. This year heralded an extension to the sales division that, in spite of having no direct salesforce, has been quite successful both in offsetting any decline in orders due to the current recession and, for about half of our applications, rendering remarkable increases in sales volume. During this period of evolving program application, the company has prospered, growing from 35 millions in gross volume to just less than 70 millions. This is a remarkeable achievement in a climate wherein an excess of 540 businesses have been failing each week! And, there is good evidence that this correlation between program application and company growth is a causal one.

Finally, not mentioned in last year's presentation have been systematic program applications in a region of a large insurance company, to a branch of a major pest-control firm, to a large and prestigious CPA firm in Detroit, to one of the five largest book binderies in the U. S., to a small distributing company in Chicago, to a plant of one of the country's largest food-processing corporations, to a small parts manufacturer in Indiana, to a large Indiana banking operation, and so forth. Again, these applications have entailed different managers, work samples, operational procedures, environmental challenges, and many other variations, yet all have been accompanied by from solid to spectacular increases in worker productivity. we believe that these data, some of which now are published in solid, reputable, edited journals, go a long way to supplying an answer to questions regarding (1) whether or not management "style" can serve as an effective combatant against the current productivity slowdown, (2) whether such a "style" indeed exists, (3) whether "it" can be learned by ALL managers, and (4) whether is can be applied within a wide variety of settings to different work populations. We believe that these data supply an optimistic albeit yet tentative answer of "YES" to all of these concerns.

Since the IREAPS presentation of last year, I have been blessed with

numerous "eye-opening", industry-relevant experiences regarding the manufacture of ships that, while extraordinarily illuminating, also were somewhat overwhelming in terms of both the amount and complexity of information input. This input resulted from (1) an opportunity to present our work to top Naval Personnel of the Materials Handling Division of the U. S. Navy, (2) participation on the ad hoc Human-Resources IREAPS task force where I was exposed to truly outstanding experts, and (3) was given opportunity to visit two compact shipyards for purposes of proposing a Human-Performance-Engineerings (HPE) application. In addition, I was privileged to sit in and present to the summer SNAME, SPC-9 panel meeting in Seattle, and was invited as an addressee by Mike Gaffney of the NRC to represent our work to a symposium devoted to contrasting approaches to human resource development. While I learned much from these opportunities, I also learned that there was much more yet to master, thereby still leaving me relatively uneducated about shipbuilding procedures and practices. Indeed, the confusion that I sometimes felt from these experiences surely supplies justification for retitling my paper from its present, rather grandiose moniker to... "AI'? EXPERIMENTAL PSYCHOLOGIST'S VIEW OF ALICE'S WONDERLAND, OR THE SNARK REMAINS A BOOJAM."

In fairness, however, I believe that I did learn some important things about the shipbuilding industry that bear importantly upon any potential contributions that might be made through an application of HPE to reversing sagging productivity therein:

1. At the end of World-War II the U. S. was building approximately 50% of the world's ships. Currently, our country is building less that 2% of the ships, and even this figure might be lower were it not law that the Navy employ national resources in this connection.

2. While it may be law to build Navy ships with U.S. resources, it apparently is not necessarily the case that the private sector be involved. The navy currently does much of its own repair work, and purportedly has conceived of the possibility to even build them (again?) were conditions "appropriate." Clearly, one such condition has to do with whether the private sector can be at least nominally competitive with current non-American manufacturers. This is an especially acute problem at present since the U. S. government recenly has committed to rebuilding the Maval fleet. It thus is imperative that our private sector respond in such a way as to guarantee its full involvement in this committment.

3. The private sector apparently recently has begun to respond to certain of these challenges with truly advanced technological alterations. For example, some yards have experimented with innovations in production control procedures. These include numerically controlled, automated cutting, computer aided design, and numerous variations on zone outfitting. However, much variability across and within yards presently exists in terms of inclusion of these and other new procedures.

*A* The preceding is complicated by the fact that, unlike most U.S.

manufacturing undertakings, shipbuilding more closely resembles building-construction rather than well-developed assembly-line operations. And, building-construction undertakings long have been known to defy easy changes to accomodate automation procedures, modern production control innovations, or efficient material-handling processes. These factors complicate the development of sound work-measurement procedures. This latter especially is problematic since,...

5. shipbuilding remains a very labor-intensive undertaking likely in part because of the aforenoted problems.

6. In spite of the current, intensive efforts to develop and deploy advanced technologies in this industry, there surprisingly only recently has been much attention given to the systematic development of the so-called "human resource." In this connection, only recently has there developed an awareness from other labor-intensive industries of the numerous undertakings that have been tried in this connection as well as of the corresponding direct and indirect potential gains in productivity that can result.

By "indirect effects" is meant that certain changes wrought through human-resource development typically are not immediately and directly reflected as graded increases in measures of work rate by individual workers. Instead, more work output is achieved through programs that reduce absenteeism, tardyism, turnover, accidents, and increase work quality. There now are numerous illustrations of the beneficial effects of such programs from the automobile, food-processing, and "hard" manufacturing industries.

By "direct effects" is meant that human-resource development directly has resulted in increases in actual work rate, i.e., more output per unit time per worker. Judging from my aforemention committee involvements this last year, the shipbuilding industry only recently has become more aware of programs employed by others that result in such direct changes. Certain of these programs have focused on improvements in the so-called ENVIROMENT-WORKER interface, capitalizing upon current knowledge on how to tailor features of the work situation so as to capitalize on the sensory and motor capabilities of the worker. The general intent of these programs has been to remove obstacles that encourage unnecessary complication, behavioral reduncancy, competing actions, and/or that minimize "drain" on worker sensory systems to accomplish their assigned tasks. Another way to accomplish much the same effects have been through programs that attend to problems of material supply, flow, and quality. These programmatic approaches thus also increase work rate through environmental alterations. In effect, all such programs that are concerned primarily with environmental-worker interfaces conform to what Hackman (1978) terms *'environmental tailoring" to capitalize upon apparent worker capabilities and/or needs. Appropriately, these have been categorized as human-factors programs, and those that in general have proven most effective incorporate many of the well-known principles of sensory and motor

function researched some time ago by human-factors psychologists.

Yet another and perhaps even more recent development in connection with direct approaches to increased productivity through human-resource development in your industry has been an increasing concern regarding the possible utility of various WORK-IMPROVEMENT PROGRANS. Here, rather than "environmental tailoring," focus instead is upon "worker tailoring" (Hackman, 1978). The general idea is to institute means to counter the purported decline in work wrought by what pollsters claim has been a negative shift in worker attitudes and the so-called "work ethic." However, this general approach has been accompanied by considerable skepticism as well as controversy within your industry (as well as others). The major reason for skepticism has been because of the widely-voiced contention by some that work-improvement programs are, at worst, unproven or, at best, likely to exert only short-term beneficial effects (cf., Kendrick, 1980).

Certain of the more authoritative recent surveys at least **partly** attest to these skepticisms. For example, Woodman and Sherwood (1981), in a summary of reports on the effectiveness of group and/or team approaches to work improvement, concluded that none provided convincing proof of effectiveness in increasing work output. Illustratively, they showed that many of the projects reported upon were flawed because they did not employ procedures needed to rule out alternative, plausible explanations of purported effects. Even more serious was the fact that almost none of the reports included provisions to show effects in other than single work situations. Finally, even had some group approaches proven convincingly effective, carefully documented figures that reflected cost-benefit relationships were even more rarely available.

While it is not clear that quality-circle procedures qualify as a "group" approach to work improvement, it is important to note that thus far there is only a single published report that incorporated the safeguards necessary to a convincing conclusion regarding the possible effectiveness of this strategy (Hendrix & Ovalle, 1982). Regretfully, these authors were unable to show that their application of quality circles had any effect on work output, let alone any of the other effects currently claimed by those that champion this work-improvement approach.

An even more wide-ranging set of surveys by Cummings and Molloy (1977; 1978) of work improvement programs, sponsored by The National Science Foundation, recently were released. These authors concluded much the same regarding the effectiveness of group, job restructuring, objectives-setting, flexitime, Scanlon-Plan, and various other approaches as did Woodman and Sherwood (1981) did about group and/or team approaches to work-improvement. Cummings and Molloy (1977) noted one exception, however, an so-called "new kid on the block;" namely, Organizational Behavior Modification (OBM, after Luthans & Kreitner, 1975). (N. B., Organizational Behavior Modification is but a subset of what is termed herein the Human-Performance-Engineering, HPE, approach. Also note that there

is another perhaps even "newer kid on the block" that, while not unlike certain of the approaches analyzed by Cummings and Nolloy, nonetheless is seen by some as also holding great promise as a work-improvement tool. This approach, the so-called Quality-of-Work-Life or OWL philosophy, while not the focus of this paper, will be touched upon later.)

Our data, partly summarized last year and some of which is "In Press" (Anderson, Crowell and colleagues, five articles, 1981), buttresses the optimistic view of Cummings and Molloy (1977) that, at last, it may be possible to directly alter and then maintain indefinitely any work behavior of any worker in any setting. As noted earlier, much of the research with the HPE technology has incorporated all of the safeguards needed to (1) rule out alternative interpretations, and upon which to (2) base the contention that the techniques involved can work in any setting and/or set of circumstances. Moreover, careful documentation of program costs and benefits invariantly (3) has permitted the conclusion that out-of-pocket organizational costs (but not of efforts) are miniscule and (4) bottom-line benefits of a minimum of 10% increases are standard outcomes. Moreover, most of our applications have been in effect at least four years (Emory Air Freight successfully have maintained a primitive version of an HPE program for 11 years), thus (5) directly countering the view that all work-improvement programs are short-term in effect.

In the latter connection, please recall the furniture manufacturing project presented last year in which a 14% increase in overall plant efficiency was directly traceable to department-by-department applications of HPE ingredients over *a* four-year time frame. As noted, another year has passed, and the program has continued to be refined, refreshed, and maintained. It thus is possible to employ the data collected over this latter period to evaluate concerns regarding program longevity.

MEAN DEPARTMENT EFFICIENCIES

| | Preprogram 1977- | Spring 1981 | Summer 1982 |
|---|---|---|---|
| **Indiv. Appl.** | | | |
| Fbrgls | 94% | 104% | 109.1% |
| Uph | 85.2% | 87% | 101.8% |
| Pch Prs. | 88.5% | 98% | 98% |
| Weld | 70.3% | 79.5% | 92.5% |
| Vrtbra | ---- | 85% | 95.7% |
| **Group Appl.** | | | |

| | | | |
|---|---|---|---|
| Pol & Buff | 86.3% | 99% | 98.2% |
| Pltng | 84.3% | 89.9% | 92.9% |
| Mn. Ln. | 94% | 99.4% | 99.5% |
| PLANT | 84% | 96% | 97.1% |

Table 1: Mean department efficiency changes prior to and following HPE program application and maintenance. The first five departments entailed program application on an individual basis and the remaining departments entailed group application

And, even more important, the earned ratio has continued to increase. Earned ratio is calculated as the number of hours it would have taken at standard to turn out the product for a given week divided by the number of actual hours expended. This index thus takes into account both direct (product relevant) and indirect (nonproduct relevant) labor hours. The ratio had been a steady .54 at project outset, rose to .66 when presented to you last fall, and presently is .672. Indeed, the earned ratio for every department has continued to increase!

PROPOSITIONS THAT FOUND HPE APPLICATIONS

The technology of Human Performance Engineering is predicated upon certain propositions. These include:

1. People do not change, behavior does.

The primary message here is that any work-improvement program will be successful the degree to which it is directed at the actual actions of employees, not at such inferrables as personality traits, motives, attitudes, or other so-called internal or "mental" characteristics. Indeed, there is considerable scientific evidence that the latter, by whatever definition, more likely will change as a result of behavior changes rather than serve as the cause(s) of human action.

2. All human behavior is lawful.

By lawful is meant the same as any scientist means by laws. It means simply that human behavior is controlled by events, circumstances, and/or conditions in the world, and that these "controlling" relationships can be objectively specified. As for any science, knowledge of these laws permits accurate prediction, understanding, and even systematic alteration of the behavior subsumed by them. Indeed, we know of no behavior that is not lawful, predictable, or that cannot be understood in terms of the operation of said laws.

3. Behavior is docile.

There appears to be no behavior that cannot be changed by use of what we presently know of the aforementioned laws. Human action seems eminently malleable. It putatively is readily molded through the so-called "processes" of acculturation and other environmental determinants.

4. We now know enough about the laws of human behavior to apply them to obtain and then maintain any human performance needed in the world of work.

Clearly, there is much left to be discovered about human behavior. However, major strides have been made in this connection during the past century. At present, it seems a safe conclusion that enough progress has been made to achieve **almost** any reasonable change desired of human work behavior.

5. Increases or decreases in productivity always can be traced to and thus are the byproduct of the nature, quality, and quantity of human action.

We believe that the "bottom line" of any organization depends upon what both front-line operatives and managers alike do or do not do. As such, productivity problems can be viewed in terms of too much or **too little** of those actions critical to missions of the groups that make up respective departments, departments that form divisions, and divisions that give rise to the organization as a whole (cf., Crowell & Anderson, 1982).

One major deduction from this proposition is that reversing the productivity slowdown is a matter of altering those various critical human actions within organizations that currently impede innovation, development, and efficient performance.

6. These propositions, if correct, permit the deduction that the degree to which any work-improvement approach is effective is the degree to which the laws of behavior are operative therein, either by design or serendipitously. By this deduction, Quality-of-Work-Life and/or Quality-Circles approaches, to be successful, must capitalize on the presence and the efficient operation of these laws. However,...

7. Some work-improvement programs better provide for the efficient operation of a broad spectrum of what currently is known about behavior than others. On this view, programs that do not explicitly provide for the use of such laws are not likely to be either as efficient and/or as effective as those that do.

These propositions and the relevant associated research permit, in our view, relevation of theso-called "management style that managers (purportedly) have not learned yet," as called for by pollsters. To extract maximum work from our large workforces, it accordingly is our belief that...

8. Managers must become' Human Performance Engineers. This means that they arrange their work situations so that they systematically can introduce, alter, and then maintain the operation of those variables, factors, and conditions that we now know to be effective in work settings. And, while we know of perhaps 100 or more such variables, there are a few that are so seemingly universally potent that they qualify as fundamental to any program of effective HPE. These can be enunciated in terms of the Steps to HPE that should be followed in ANY program application. In other words, the following steps are recommended in order to maximize the efficient utilization of the greatest number of laws presently known to be relevant to behavior change.

In specifying these steps, it is possible to "kill two birds....," so to speak. In the NRC-sponsored debate on HPE versus QWL, an attempt was made to minimize the importance of the former approach on the grounds that it was little more than traditional Industrial Engineering with a little psychology thrown in. Admittedly, there are certain similarities between these characterizations since both rely heavily upon measurement procedures. But, there are pivotal differences in techniques, and in the reasons for their presence in work settings across these "paradigms." Thus, an attempt will be made to highlight some of these critical differences in the following "steps to Human Performance Engineering."

## STEPS TO SUCCESSFUL APPLICATIONS OF THE HPE APPROACH

STEP I: We recommend that considerable time be spent in locating where best to begin an application of an HPE program within an organization. Several considerations are involved in this choice. One of these is where (1) there is a heavy labor concentration. On the view that human behavior forms the cornerstone of success (or failure) for organizations, a second consideration derives from an examination of existing measurement systems that might reflect upon (2) large "disparities" between company expectations and current employee performance levels. The larger this disparity, the more compelling the site for program application. A third issue has to do with (3) ease of program development. Complicated tasks, large and "rambling" work areas, a history of workers and/or manager resistance, and so forth all represent concerns here. A final consideration is that of "representativeness." If, for example, program development in a portion of the organization does not provide the foundation for extension to remaining portions because of marked idiosyncracies between settings, much wasted time and effort can be the result.

These criteria of (1) labor concentration, (2) evidence of pronounced disparity between expectation and obtained performance levels, (3) ease of program institution, and (4) idiosyncratic program-development demands should be considerered with the axiom... "begin with the smallest unit likely to show effectsc.

perfect procedures, **systematically** extend to the next unit, and so on." These considerations guided us in, for example, choosing housekeeping to initiate an HPE application rather than food, sales, building maintainance, or front desk operations in hotel: in choosing the fiberglass rather than upholstery department of a plant and the plant per se rather than the corporate white-collar workers or delivery or sales in our manufacturing example; of attending to teller service rather than selling or other branch functions; why we chose service rather than sales to "upright" a failing branch of a large pest-control organization (see Figure 1), and so on. In each case, the presence of all of these criteria dictated where to initiate HPE procedures. And, it should be clear that these considerations and corresponding decisions represent quite a different collection of issues than those that typically guide standard industrial engineering applications.

STEP II. This step entails development of a mission-relevant measurement procedure that, if at all possible...(l) Reflects individual work performance, **(2)** Can be collected on a daily (or as frequencly as possible) basis, and (3) Is behaviorally relevant.

By "mission-relevant" is meant that, whatever the measurement system, changes should directly impinge upon the goal(s), purpose(s), and/or outcome(s) of the organizational component where HPE is applied. The reason for INDIVIDUAL MEASUREMENT is that, although sometimes not possible because of preeminent work arrangements and task requirements that appear to defy nongroup approaches, such is the only way to ensure maximum contribution from every employee. Much the same rationale underlies the reason for FREQUENT COLLECTION OF MEASURES. For example, the more frequently it is possible to objectively sample (monitor) the work of every employee, the less the delay in introducing behaviorally potent variables. And, there is considerable scientific evidence that DELAY can result in pronounced attenuation of said potency.

The stipulation of BEHAVIORAL RELEVANCE is perhaps the most important ingredient of those listed for this step. Any HPE application simply cannot be effective in the absence of this criterion. Behavioral relevance is achieved by the presence of three quite different conditions. First, a measure is behaviorally relevant only if each worker UNDERSTANDS, i.e., can verbalize, explicitly what actions (behaviors) s(he) must change in order to alter the value of the measure. Second, increases on this index of work output will be attenuated the degree to which the worker's actions do not fully CONTROL the values of the measure. Only the individual-worker's and not the actions of others must be able to produce changes in the measure. Finally, the laws of behavior can be invoked more efficiently and effectively when little delay occurs

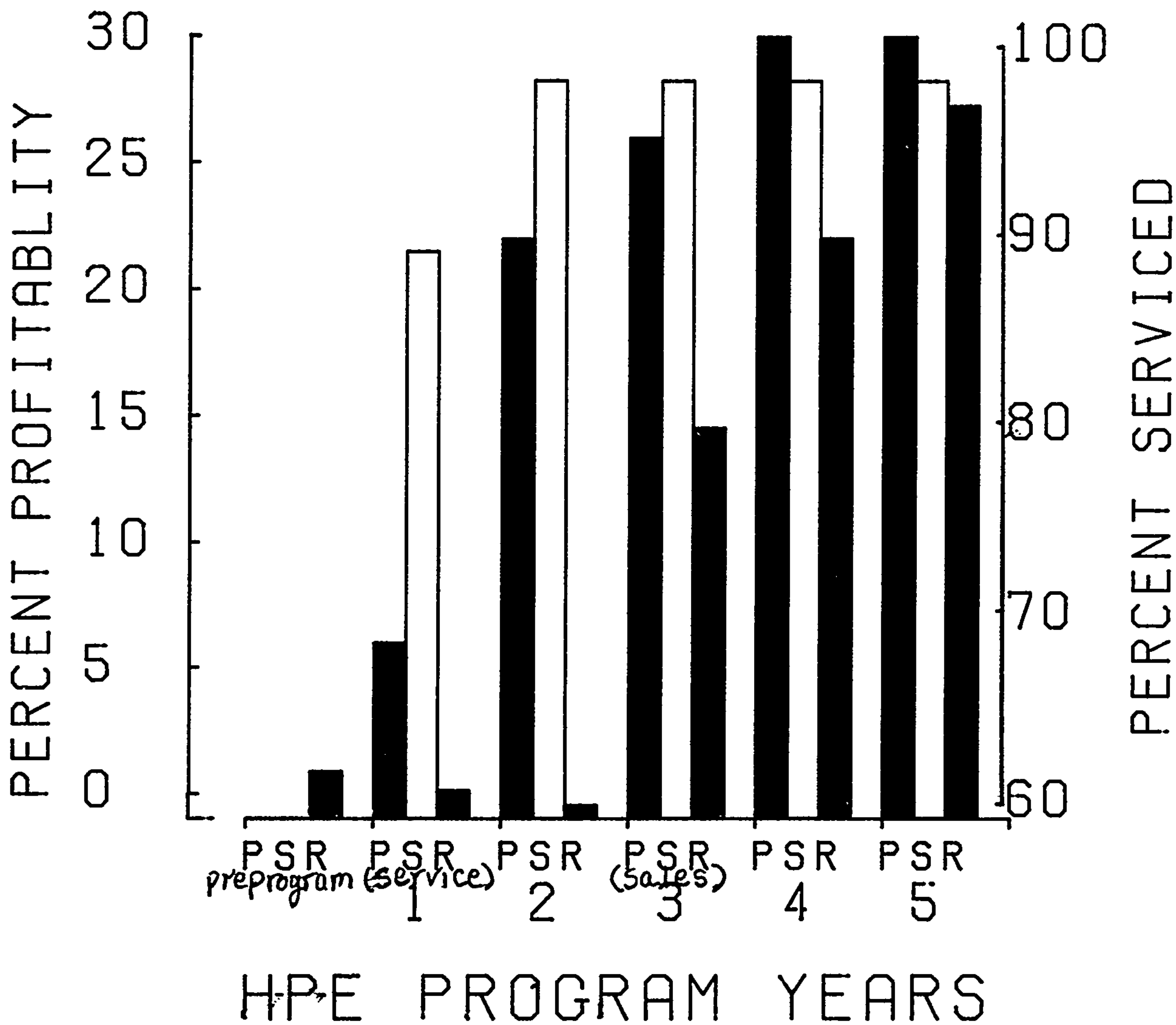



Figure **1:** Correlated changes in profitability (P), percent customers serviced (S), and revenue (R) with the temporally-staggared introduction of respective H-P-E applications to the service (service) and sales (sales) operations of a "failing" branch of a major pest-control company

between worker performance and collection of the measure.

We have a large amount of data that reflect on each of the preceding stipulations listed for this step. Probably little further embellishment is required regarding the issue of MISSION RELEVANCE. Suffice it to say here that whatever measure is used to index worker performance, it must reflect the occurrance or nonoccurrance of those key employee actions that are essential to fulfillment of their contribution to the mission to the organization. This can be assessed by calculating correlations between changes on this measure and the standard indices of productivity/profitability used by the company. In one of our sales programs, for example, we measured number of personal, face-to-face initial and followup contacts with prospective customers (see Figure 6 below). If increases on these measures had not been highly correlated with increases in new and pending sales and property listings, they would have been discarded for other behavioral evaluations. In an ongoing bank program, we developed an elaborate measure of the "first-class treatment" that a teller may/may not dispense to customers. If changes in this measure proved not to correlate highly with productivity measures such as customer-account retention, increases in the latter, a reduction in complaints, etc., we would have to discard it and begin again. Fortunately, it often has been possible to use extant measurement systems, thereby automatically providing a guarantee of mission relevance.

A good example of what can happen when INDIVIDUAL MEASUREMENT is not possible comes from the preceding furniture-manufacturing example. Table 1 shows that where individual measurement is in effect, both larger productivity gains that more easily can be maintained are more likely than for our "groups" applications wherein production-control procedures and task requirements defied individual assessments. As regards BEHAVIORAL RELEVANCE, consider first the issue of employee UNDERSTANDING. In our manufacturing example, we used the extant measurement system in effect, namely, daily efficiency. This was transduced by each worker completing a daily form that designated part number, time taken to perform the work, and number of pieces. These data were entered into the computer, efficiencies calculated for work on each part, all then being averaged to provide an overall index of daily work efficiency. Simple public display of this information for each individual on an daily basis resulted in across-board efficiency increases over an 8-week period of 5%, 8%, 3%, 5%, 6%, and 13%, respectively for the fiberglass, punch press, welding, main line, plating, and polishing and buffing departments. These departments were both supervised and staffed by all-male work populations. In contrast, the all-female upholstery department showed a meagre 0.5% efficiency gain over a similar 8-week period of simple public display. The explanation for this difference in effect was that none of the members of the upholstery department, including the manager, understood what the measure meant in terms of their daily activities. But, each showed steady increases thereafter once they and the manager were COACHED to "understand" this index in terms of the behavior changes each needed to make. The very same problem occured in our hotel HPE

applications. Virtually every hotel has some form of a checklist measurement system for assessing the quality and quantity of cleaning performed by their housekeeping staffs. Yet, one of the major and chronic complaints of hotel management has been over unusual difficulty in getting and maintaining clean rooms. A careful comparison of these standard checklists with the one(s) that we developed provides one clear reason for the general lack of success with standard measurement procedures. Virtually all checklists that we examined were so vaguely worded, globally formulated, and incomplete that is was virtually impossible for maids to UNDERSTAND exactly what actions they needed to change in order to obtain checkmarks. Moreover, supervisors found it impossible to be objective, accurate, or consistent in their use of the instrument for the same reasons. (These two factors probably accounted for the fact that we could find no hotel that routinely employed their checklists after an initial trial period of usage.) However, with development of a checklist that was behaviorally explicit and comprehensive, maids, housemen, and others, along with their supervisors, were able to make and then sustain the necessary behavioral adjustments needed to increase the overall quality and quantity of cleaning activities. It is worth adding that one major difference between ours and other checklists is the unusual detail that we include. This can be appreciated from the fact that most lists require few more than eight to 12 checkmarks while ours, for example, often involve 70 or more. Figure.2 is the list that we used in the hotel project that was summarized at last years' IREAPS presentation.

As regards the issue of CONTROLLABILITY, there are numerous examples of behavioral variables that have little or no effect on measures over which the actions of individual workers have little influence. The measure of number of "sales" is an excellent example. Sales managers historically have lamented over their inability to obtain marked and/or lasting changes on this measure. One clear reason for this is that number of "sales" is not exclusively determined by the behaviors of their sales staffs. We again can draw from our furniture-manufacturing HPE application to exemplify this problem. Although all sales are implemented by an indirect sales force, certain of the latter work individually and certain others are employed by distributor organizations. In the former case, it was possible to develop behavioral measures over which sales reps have full control, but we were prevented this opportunity where large distributor organizations were involved. We thus were forced in these latter cases to focus our HPE efforts on the standard measurement of sales output. By using behavioral measures that were "controllable" by the individual sales reps, we were able to increase their 1981-2 sales volume anywhere from 5% to a whopping 231%! In contrast, volume decreased modestly during our HPE

## LOBBY CHECKLIST

Houseman________________ Supervisor____________________ Date__________

yes no

Front Doors

1. Glass
2. Stainless door frames
3. Thresholds
4. Mirrors clean
5. Grating clean
6. Red quarry clean

Arcade

7. Walk-off mats vacuumed
8. Baseboards at optical shop
9. Arcade pillars-base
10. Phone booth floors
11. Phone booth walls
12. Phone booth doors
13. Phone booth vents
14. Telephones
15. Hanging ash trays
16. coffee-shop wrought iron
17. Exterior coffee shop brick
18. Art display base board
19. Arcade doors- stainless
20. Above door jams
21. Lettering above door jams
22. Shutters- 6 panels
23. Flame room exterior windows
24. Danish Room door
25. Danish Room vestibule
26. Floor-Smoke Shop entrys
27. Exterior Smoke Shop windows

Lobby

28. Wash mosaic wall
29. Smokey mirror
30. Dust all display boards
31. Fill & clean standing urns
32. Polish vertical Brass insets
33. Return air vents clean
34. Viking Club doors dusted
35. Viking Room doors dusted
36. Cigarette machine
37. Fireplace glass (both sides)
38. Fireplace ledge washed

yes no

39. Fireplace brass front polished
40. Mirror columns
41. Furniture clear of det
42. Carpeting as good as possible
43. Glass ash trays clean

Front Desk

44. White partition wall
45. Black marble
46. White base board marb
47. Plexiglass guard
48. Display counter
49. Telephone counter (sc
50. Bonnie Bell case
51. Plastic plants
52. Stairwell fixture & signs
53. Announcement board
54. Railings & glass inse to Mezz
55. Mezz stairs
56. Escalator stainless
57. Escalator Panel
58. Under astro-turf
59. Custodial closet

Elevator Foyers

60. Corners all around
61. Radisson Hotel displa
62. HAB display case
63. Ledge over HAB entry
64. Size shop windows
65. Elevator door frames
66. Inside elevator carpe
67. Inside elevator walls
68. Sweep & mop red quarr tile
69. Sweep & mop lobby ter
70. Clean reservation off

4 X per year

71. Liquid gold Viking rm. entry
72. Dust Viking ship over door
73. Clean central lobby fixture
74. Mirrors over escalator

Figure 2: The checklist measurement instrument for one of the H-P-E applications to the public accomodations industry reported by Anderson et al., 1982

applications to the sales measures supplied by the larger distributor firms. (Even the latter may be viewed as a success when compared to the much larger decline in volume of a noncomparable control group, cf., Cook & Campbell, 1978, that was not exposed to the HPE program.)

As regards differences between the above HPE concepts and those of the industrial engineer, both admittedly rely heavily upon measurement. However, such systems usually are developed by the IE without explicit concern for changing individual worker behavior. Instead, such measurements, along with being used to develop standards, primarily are used for developing new or trouble-shooting old production-control procedures, constructing work schedules, projecting future labor needs and/or costs, and so forth, all of which are both laudable and desireable purposes. The difference, however, from an HPE application is that such systems typically are not developed for the explicit purpose of altering human work activity in terms of what is known about the laws of human behavior.

STEP III. We are in accord with the IE regarding the importance of standards. However, the reasons for our agreement again appear to differ somewhat. Standards, when appropriately developed and introduced, capitalize upon several important behavioral possibilities one of which is that the more explicit and objective the statement to workers regarding exactly what is expected in behavioral terms, the easier and more quickly are those expectations achieved. This "postulate" is not simply a restatement of the standard view of goal setting. We now know, for example, that goal setting per se only will have marked and perduring influence in changing human performance the degree to which these goals are expressed in highly explicit, well articulated behavioral expectations. Illustratively, a goal for sales is much less useful as a prerequisite for changing behavior than is one expressed in terms of number of appropriate client contacts. The former is an OUTCOME measures that, in part, is dependant for increases upon the latter, which is a behavioral measure. Moreover, maintenance of these changes is not likely unless a means is developed by which both the behavioral expectations and how to achieve them are made chronically conspicuous to all concerned.

Thus, this step consists of the arrangement of a complex of ingredients and variables, including (1) development of work expectations, (2) formulation of the latter in behavioral terms that both designate exactly what actions are required along with their required rate and pattern (e.g., a given number of calls within a carefully-defined customer population), and (3) a procedure wherein this information can be kept chronically conspicuous. Again, there are considerable data on the potency of this step and/or the variables involved. In connection with the need for behavioral explicitness, consider the effects of the simple introduction of expectations, expressed in behavioral terms, for student employees that worked for the UND Senior Bar during the 1981-2 academic year. Historically, student attention to cleaning in both serving; eating, recreational, and the lavatory areas has been so bad as to defy

description. The result has been a chronic struggle over the years between this facility, state health officials, and its constituents to achieve a safe margin of cleanliness. General managers chronically have appealed to their student-employee colleagues to clean their respective areas better or risk losing their place of work. No visible changes ever seemed to occur, however. We thus developed a behaviorally-relevant measurement procedure that, among other things, included the development of checklists of exactly what actions were needed to achieve a clean station for each of the 11 different areas (different checklists for each!). Then, after covertly (secretly) recording on these lists how each of the 30 student-employees cleaned their respective areas, we simply displayed the checklists at each station and called them to the attention of each student. The average percent of items cleaned prior to posting these expectations was 49.9% for the 30 employees, but rose to 55.2% upon display and explanation of the lists. Moreover, because display was possible at each work station, these expectations were kept "in front" of workers, a factor that likely was partly responsible for maintenance of this gain over several months. These data are shown in the left portion of Figure 3.

A similar result was obtained from our aforenoted HPW bank project. Following development of our behaviorally-explicit definition and measurement procedure of "first-class service" (involving placement of microphones at each teller station to record, and a reliable scoring system to measure the quality of teller transactions), we simply introduced the scoring system and associated behavioral expectations in the form of a memo and group meeting with the tellers. Prior to introduction, tellers averaged 62% of the behaviors that defined "first-class service," this in spite of having chosen a branch acknowledged to be the best of the 19 for this particular organization. Introduction of behavioral expectations resulted in an immediate 15% average increase in teller courtesy, thereby raising their service from third- to at least second-class quality by our definition. However, since we were unable to discover a means to maintain the conspicuousness of these expectations, average courtesy showed a decline within about 7-8 days following introduction of the memo. But, as soon as expectations again were mentioned by the branch manager, courtesy picked up again. Some of these data are shown in Figure 4.

A final illustration comes from a recent HPE application within the manufacturing concern noted above that currently is experiencing harsh competition with the Tiawanese. While an IE-type measurement system has been in place for several years in the plants of this company, it unfortunately proved insufficiently behavioral to be of

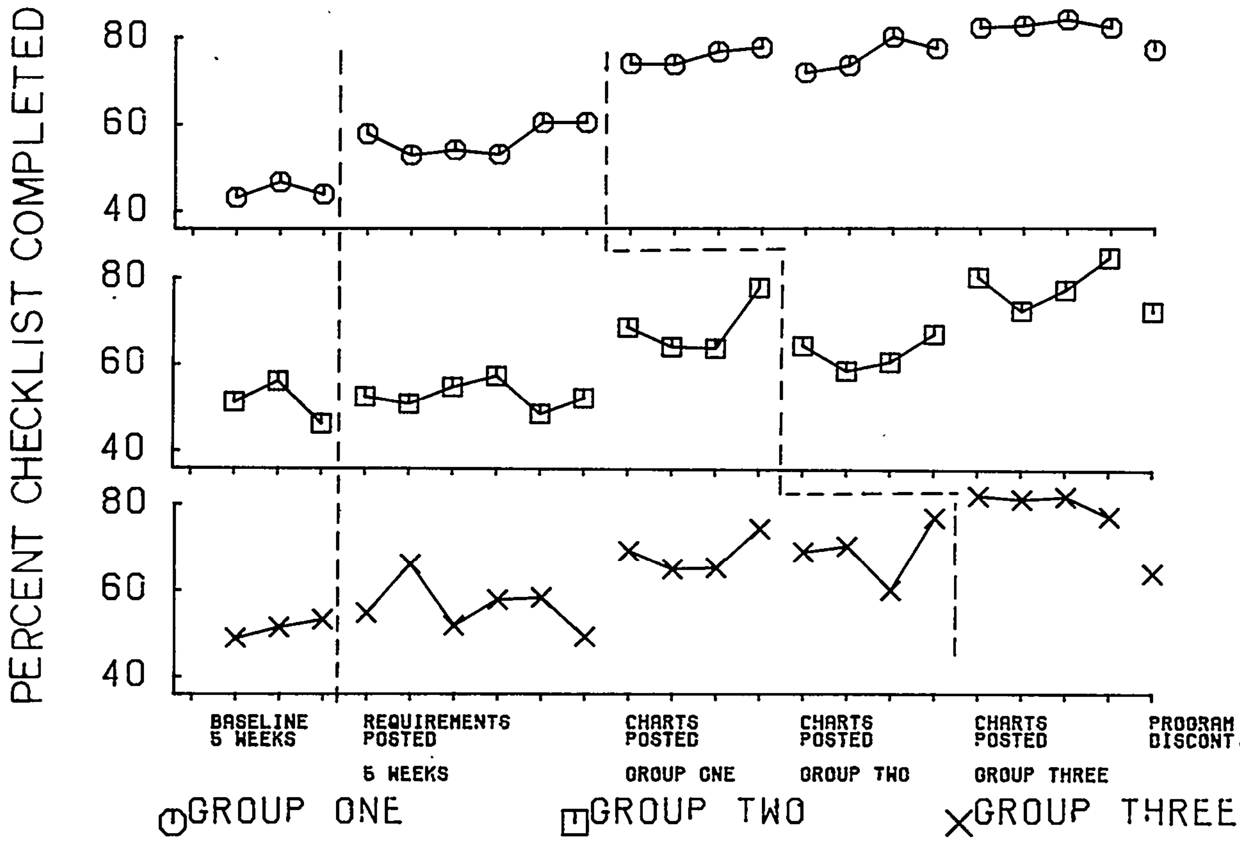



Figure 3: Mean percent items checkmarked for each of three, randomly-formed groups of student employees of the University of Notre Dame Senior Bar. Each checkmark represents acceptable performance on one aspect of a total cleaning assignment. The first three points are preprogram checklist averages. The ensuing six points are for average scores achieved following public display of the checklists at appropriate work stations. Thereafter, the data reflect average changes in percent checkmarks upon public posting of scores for Groups 1 (upper graph), **2** (middle graph), and 3 (lower graph), respectively. Note that the procedure of public charting was introduced on a time - staggared basis. The final point was collected following the last day of employment for each student.

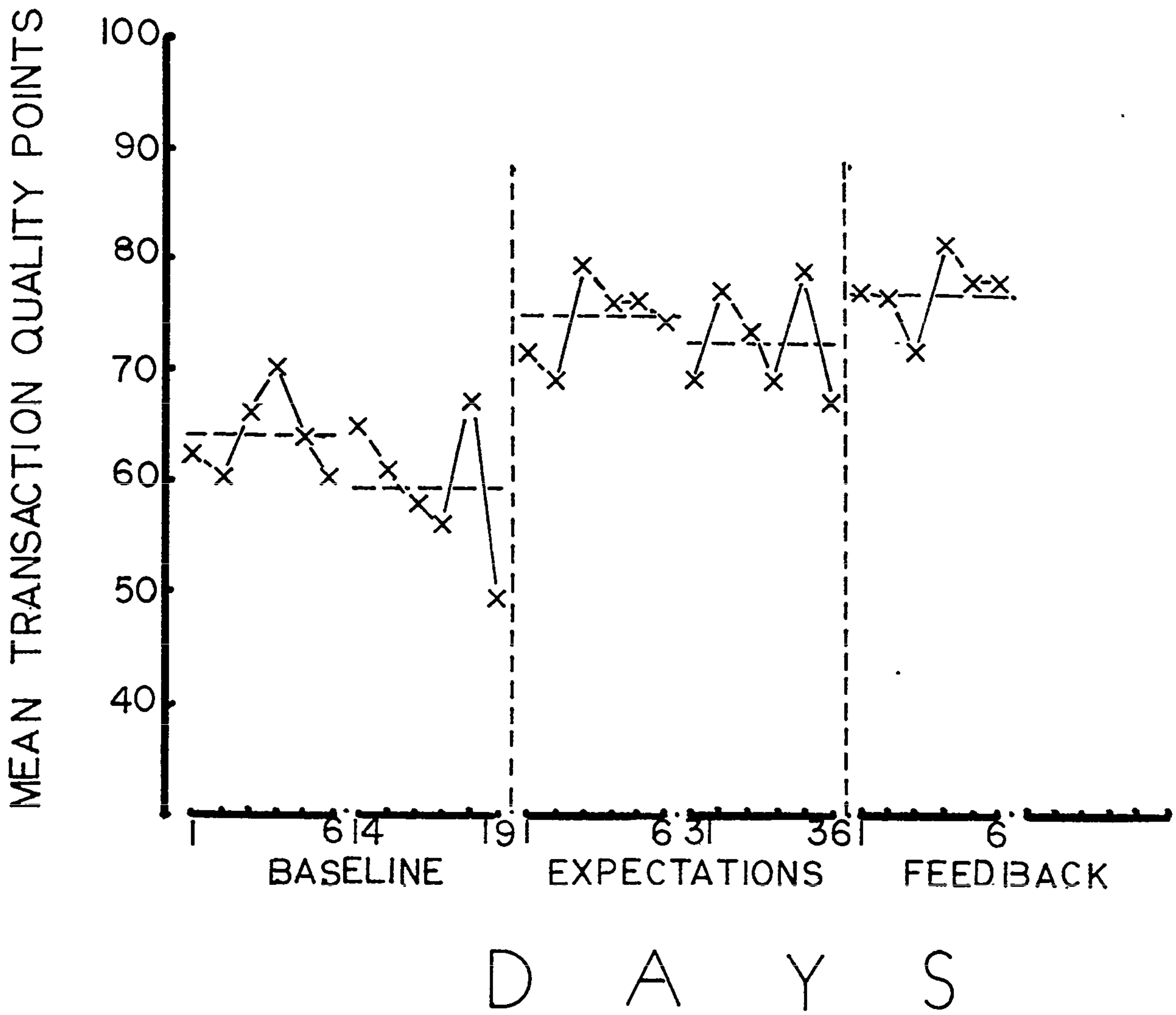



Figure 4: Mean service-quality scores, averaged across the tellers of a large branch of a major bank. The initial scores (scores for the first and last six baseline recording days) were obtained prior to informing tellers about how transactions were scored. The intermediate 12 points (first and last six recording days of this phase) were collected following discussion and dissemination of information about the scoring system to all tellers. The last six scores are for the first six recording days following public posting of scores for each teller.

as much use as we require to implement changes in worker performances. At these plants, workers operate up to five machines concurrently. Their prime responsibility (ies) is to maintain as much 'up time" as possible for each by minimizing break- and shut-downs. Unfortunately, we discovered through a laborious investigation over 100 reasons for machine "down time," and that there existed no way to discern which of these was involved for any given machine for any given "down" period. Moreover, because of this inexplicitness, no standards had been developed in behavioral terms in order to learn whether "down time" was being minimized. We reasoned that without a measurement system that "sensitized" individual workers in these connections, it would be easy for each employee to develop their own, unbuttressed expectations. We thus devised a scheme by which each worker easily could designate the exact reason(s) for down time for each machine, and then introduced it. Note well that this introduction did NOT include a statement concerning expected durations for each reason. Prior to this introduction, average daily machine "up time" ranged from about 6.0 to 6.8 hr. Since introduction of the new measurement system (sans expectations), "up time" has averaged in excess of 7 hr. daily. This amounts to a whopping 5+% increase!

Again, we believe the differences in emphasis and utility of this step for HPE and for the prototypical IE are self evident.

STEP IV. Probably there is no easier and more potent way to increase work behaviors than through the proper introduction of feedback. The key term here is "proper." While there remains much research to be done regarding all of the many conditions that define this term, there are some guidelines in this connection that have nominal empirical validity. First, (1) we believe feedback should be conspicuous, (2) ever-present, and (3) freely available for scrutiny by the individual worker and his/her "boss." Our findings are that improvements thus likely will be greatest if feedback is given in the form of individual charts that are posted in a conspicuous place where the manager and worker alike routinely can see them. Moreover, (4) these charts should be kept updated with the same frequency as measurements are collected, e.g., daily. Further, (5) the effects on work improvement of visual display can be enhanced by daily, neutrally-worded manager statements to each worker regarding their prior scores. There also is mounting evidence that (6) feedback accompanied by promises of no retaliation... neither personal nor job status... will result in more robust, across-board long-run gains than by any other procedure.

While public posting likely will prove the best procedure, there also is evidence that (7) public anonymity also is important. Here, the idea is to provide for each worker a context about how others are doing with respect to her/himself, but to do so in a noncompetitive and nonthreatening manner. Personal "threat" and competitiveness with colleagues can breed unwanted discomforts, counterproductive actions, and low esprit de corps. What is wanted instead is self-competitiveness within a context of fairness

(objectivity) and balance. By being able to visualize how one is doing compared to others without embarrassment or unusual conspicuousness, workers feel emotionally more able to make the work adjustments appropriate to organizational expectations. Moreover, by encouraging self-competition, it is possible to "spice" otherwise monotonous and/or uncomfortable working circumstances.

While space does not permit citation of all of the direct and circumstantial evidence regarding these directives for feedback of (1) conspicuousness, (2) everpresence, (3) individual availability, (4) current, (5) multimodal, (6) nonaversive, and (7) anonymous, we have collected an enormous amount of data regarding the effectiveness of the feedback step when most or all of these variables are in place. Please be referred to last year's presentation, for example, wherein across departments of the manufacturing illustration, feedback dispensed in accord with these stipulations (Figure 5, Anderson, 1981) resulted in an across-board increase of 5.8% in over plant efficiency. Similarly, indirect evidence from our real-estate sales project was that a like feedback procedure alone resulted in an over 266% average increase in number of initial "cold-turkey" contacts and in an 175% average increase in personal followup contacts. Further, during this feedback-only period, this firm rose from seventh in percent-business for their area (a position that they had occupied for several years) to, by a large margin, first place!

Feedback per se in the hotel project presented last year resulted in nearly 300% increase in quality of cleaning, as measured by average changes in checklist scores. Moreover, this magnitude of change has not been unusual for numberous HPE extensions to our other hotel projects (some noted above). For example, feedback-only reduced by a whopping 4800% the food-delivery latency of waitresses in one of our targeted restaurants, an increase in average restaurant charge of 17% and in room rate of 7.2%. In our pest control operation, simple daily posting of number of customers serviced resulted in an across-board increase from about 69% of customers served each month to 90%, or a 21% increase. In the case of the Senior Bar project noted above, posting was done on a time-staggared basis for 10 employees at a time. Figure 3 shows two outcomes in connection with feedback introduction. First, the group of 10 that were exposed to the feedback procedure first showed an immediate and sustained average increase in cleaning performance of 19.1%. Second, not surprising was a near-comparable increase in the cleaning performances of the two groups not yet exposed to this procedure. The reason that this change was not surprising is that all groups concurrently were made aware that one-third of their colleagues were being measured and charted. It is probably that those not posted "put two-and-two together" in this connection and changed their behavior accordintly... and behaved thereafter as if they too were receiving feedback even though such was not actually the case!

At the risk of gilding the proverbial lily, consider the 'results of an HPE application to the UND hockey team. Although heralded as

innately talented, this team performed poorly over the 1979-80 and 1980-81 seasons and into the one (1981-2) wherein we applied HPE procedures. We targeted for change the number of "legal hits" per minute that each player made, this requiring an elaborate and laborious scoring system. (We are aware that debate is possible over whether this measure is "mission-relevant." However, the team captains nonetheless decided that an increase in "hits" was essential to reversing their team fortunes.) Once a baseline has been determined, each team member's game scores were publicly and anonymously posted. These data, averaged for the six seniors separately from the remaining 13 juniors and underclassmen are shown in Figure 5.

These data show that, for the 13 juniors and underclassmen (all of which exhibited baseline "hit-rate" performances decidedly below their senior fellows), posting had the immediate and beneficial effect of markedly increasing the percentage of "legal hits." (The effect was not as pronounced for seniors because they already were at a high "hit-rate.") Moreover, there was coincident, instant reversal in team fortunes. The team, among many other accomplishments, launched a home-ice winning streak that went unbroken the remainder of the season!

Again, differences between an IE and an HPE approach can be discerned from the foregoing. Whereas both as noted entail work measurements, concern over how such measures integrally can be employed to alter the individual work performances of employees through the development of appropriate feedback procedures rarely is of concern by the former. Accordingly, it is unlikely that an IE would show much interest in the many variables outlined above that seem to characterize the most effective use of feedback.

STEP V. Display of performance expectations, as part of the feedback procedure, represents yet another human performance variable of documented effectiveness. Unfortunately, we only rarely have analyzed this feature separately from the feedback procedure, and thus have minimal data that directly addresses the value of this step. Fortunately, we can use the data from the hockey project to at least illustrate the potential of this factor. After simple posting for a period of four weeks, we developed performance expectations through individual goal-setting sessions. Each player individually was asked to set a realistic "hit-rate" goal that subsequently was displayed as a straight line on his chart. While only a few actually achieved, let alone were able to maintain, their expectations, all 13 of the juniors and underclassmen (as shown in Figure 5) again showed a marked increase over previous performances. Setting fair, realistic standards and then displaying them as part of the feedback procedure thus is, we believe, yet another behavioral variable of considerable importance. Locke (1968) believes that this activity

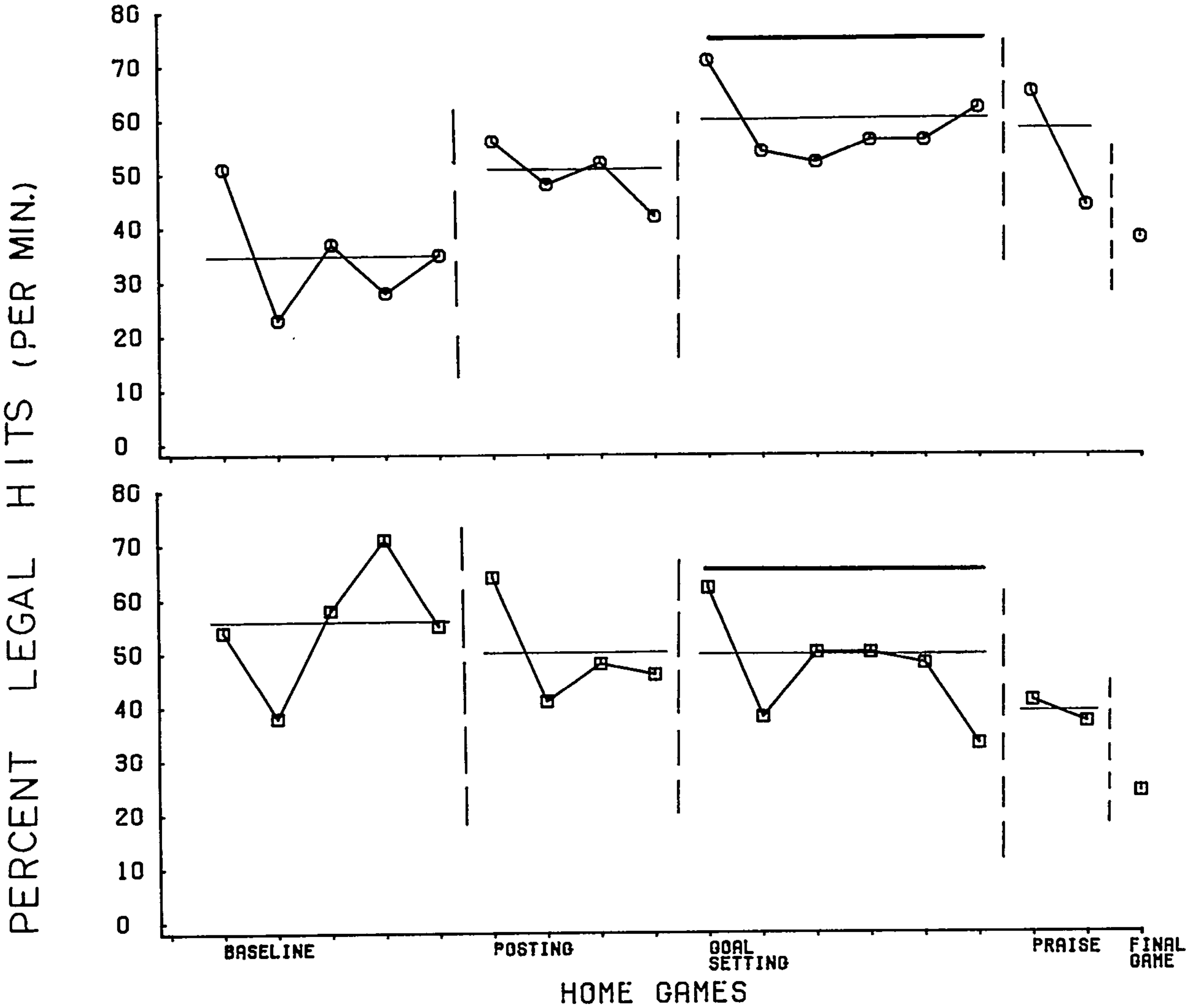



Figure 5: Mean number of legal "hits," by home game, expressed as hits-per-minute, displayed separately for (1) the 13 University of Notre Dame junior and underclassmen (upper graph) and (2) 5 senior varsity hockey (lower graph). The initial points represent average hit-rates prior to individual public display of the data. The ensuing four points show the effects of the latter. The third set of points represent "hit rate" following individual goal setting. The next two points were derived following individual recognition from the coach. The last points display performance during the final home game.

will be most effective if, perhaps in addition to the above, (1) the goal is modestly difficult to achieve, and yet (2) is "committed to" by the individual worker.

STEP VI. This step permits invocation of some of the most well-established of all of the known behavioral variables. These have to do the the known effects of behavioral consequences; namely, (1) if a positive or "satisfying" event follows a behavior, that behavior subsequently will increase in rate and vigor of occurrance, (2) if a negative or "annoying" circumstance follows a behavior, the reverse will occur, and (3) if nothing follows behavior, behavior rate also subsequently will diminish but more slowly than if a negative is involved. ACTUALLY, IT IS THE FIRST AND LAST OF THESE LAWS THAT APPEAR TO HAVE THE GREATEST UTILITY IN THE WORK SETTING. Although NEGATIVE CONSEQUENCES can be quite effective in determining the course of work behaviors, their usage also has been associated with numerous undesireable effects as well. Some of these include EXCESSIVE ABSENTEEISM, TURNOVER, TARDISM, SABOTAGE, UNION CONFLICT AND GRIEVANCES, LOWERED ESPRIT DE CORPS, AND GENERAL EMPLOYEE UNCOOPERATIVENESS. Indeed, recent surveys suggest that excessive use of negatives engenders considerable loss of employee respect for their managers.[1]

Importantly, rather remarkable work increases have been achieved through the exclusive dispensation or withholding of positive outcomes respectively for appropriate or inappropriate behaviors. And, fortunately, there are perhaps an infinite number of ways in which these variables can be implemented, many of which are likely to prove effective in almost any work situation. For example, we have had considerable success in the use of FOREMAN PRAISE AND SUPPORTIVENESS as a positive outcome for work improvement. While considerable training and follow-through is required with foremen to teach them to become the equivalent of a "social cookie," the associated gains in work improvement can be well worth it. Consider Figure 5 of last year's IREAPS presentation (Anderson, 1981) wherein the efficiencies for the worst three, the best three, and the remaining employees for four departments of the furniture-manufacturing example are averaged (1) prior to feedback, (2) as a result of feedback, and (3) when praise by foremen is added to the feedback condition. The overall gain to date from the addition of praise is 11.8% even though praise is dispensed to the three best of each department for maintaining, not increasing, their performances at 100% efficiency.

We recently added a tangible reward system in the form of specially-made, gold-colored coins that can be inserted in all of the vending machines in the employee lunch area. These coins are the equivalent of quarters and can only be earned if (1) an entire department achieves a preestablished performance goal the previous month, and (2) individuals within that department exceed by specified percentages that performance goal on any given day during the succeeding month. For example, 5-9% above the goal earns one coin, 10-14% earns two coins, and 15% or more garners three coins.

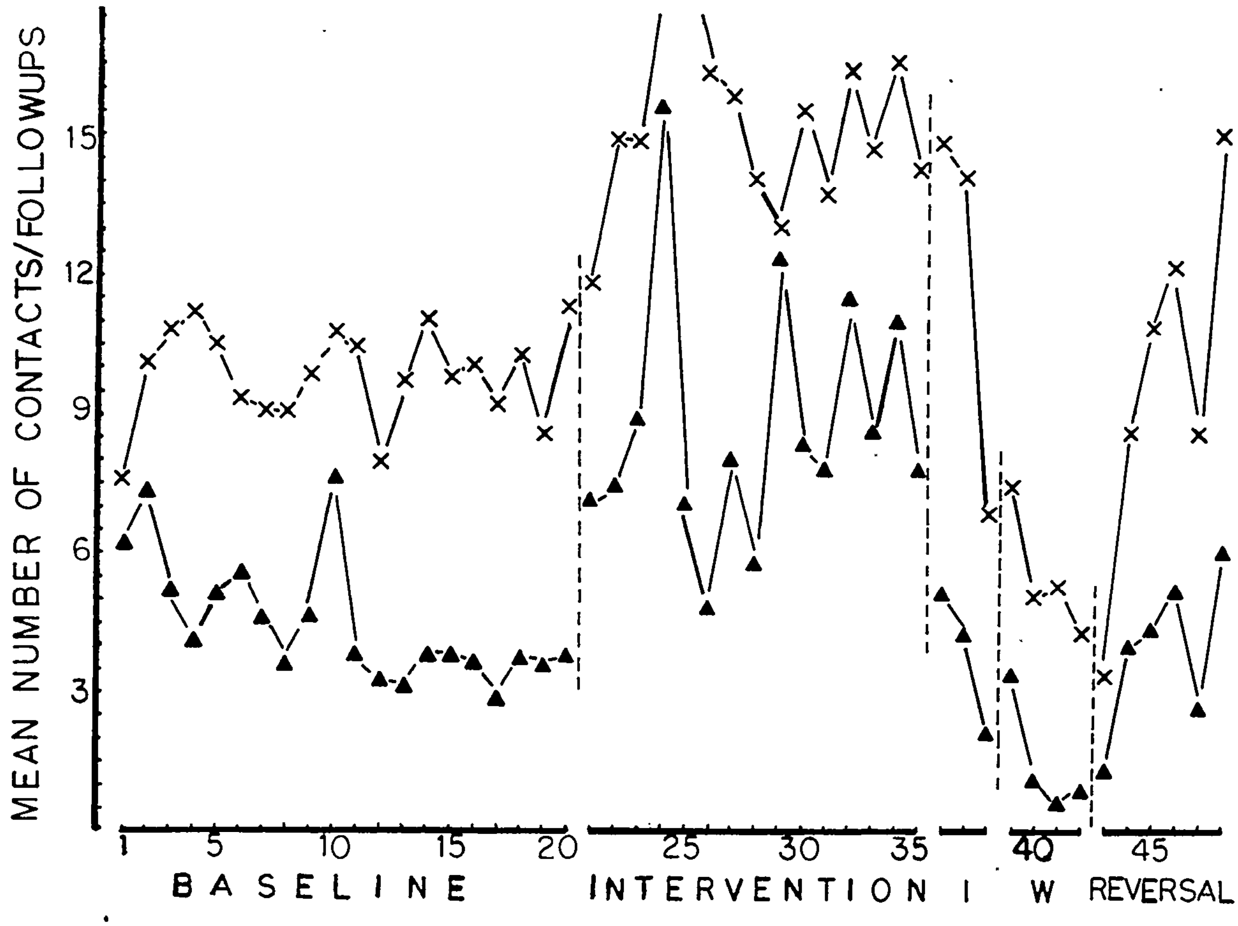
And, in addition to regular vending services and games, the company installed a "mystery" machine, insertion of five coins into which earns a (1) certificate of award, a (2) certain number of instant winners whose number corresponds to various gift-certificate amounts, and (3) and opportunity for a monthly lottery for such items as a color TV with remote control, etc.

Figure 6 shows the effects of the use of a tangible reward for performance increase in our real-estate sales project. **As** seen, across-board behavior increases were both immediate and lasting as long as this system was in place. The rewards were in the form of credits exchangeable for a wide variety of goods, the credits being earnable in terms of a complicated system that involved changes in both of the client-contact behaviors noted above.

Of course, if charted behavior changes either do not change in the desired direction or are not maintained at appropriate levels, they do not qualify for pleasant consequences. This does not mean, however, that they thereby qualify for unpleasant outcomes. Indeed, we have found that such exactly is what should NOT happen! Instead, less than appropriate activity levels should be fully ignored for best, long-run effects. As long as managers invariantly follow appropriate behaviors with consequences that are satisfying to their employees, ignoring inappropriate behavior frequently is all that is needed to achieve productivity increases that are as impressive as those cited above.

We have found that A FEW RULES OF THUMB are helpful in the use of positive consequences. First, (1) satisfying consequences should be contingent in that they should be dispensed so that the employee connects it with the targeted behavior change. Giving rewards immediately after response changes occur can be quite important in this regard, although there are others ways to make the connection if the latter opportunity does not present itself. Second, (2) it is much better to give smaller, more frequent rewards than a few large ones. Third, (3) we believe that behavioral approximations should be occasionally rewarded. This means that reward should be given once in awhile for visible (objective) evidence of "trying" even in the absence of full success. Fourth, (4) once a desired behavioral level has been achieved, that level should be followed by reward every time it occurs for awhile. Eventually, however, (5) reward frequency can be gradually reduced with no loss of rates of performance. Eventually, rewards can be given "every now and then" with good success. This latter is part of what a good MAINTENANCE PROCEDURE should entail.

When social rewards are used, we train managers to develop characteristics that parallel what we term "the four Vs." The first V stands for VULNERABILITY. By this is meant that the more sincere the praise, the more effective it will be. The second V stands for




W E E K S

Figure 6: Average number of initial (~) and followup (X) contacts made by real-estate agents, arranged by week, for (1) 20 baseline, (2) 15 reward, (3) 3 pre-program withdrawal, (4) actual program withdrawal (W), and (5) an additional six program-reinitiation weeks.

VARIABILITY. Since humans habituate to nearly everything, it is important to vary how and what is done to socially reward any given employee. The third V is for VERSATILITY. Different persons like different things. Managers must learn these preferences and dispense accordingly. This V is based on the axiom... "different strokes for diffent folks." Translated, some people prefer their praise in the form of a "pat" on the back, others in terms of "a good word," still others in a handshake, smile, or combination of these salutations. The fourth is for VISIBILITY. Social "strokes" can be made most effective when dispensed publicly for all to see. In that way, those that haven't earned such have an opportunity to experience and correspondingly learn to discriminate between their receipt and nonreceipt.

A final word of caution here. Training and then ensuring that managers (1) cease and desist from the use of negatives in connection with the charts and (2) accordingly increase the use of positives is no small chore. We have found that achievement of these outcomes require that we be every bit as systematic, programmatic, and alert as is required to achieve behavior changes from front-line operatives. It is no less a Human-Performance-Engineering task to change and then maintain key manager behaviors than it is to increase productivity-relevant operative behaviors (cf., Crowell & Anderson, 1982).

## CONCLUDING REMARKS

In fairness, the preceding has been a highly abbreviated overview of the number of steps and corresponding behavioral variables that should be involved in an effective HPE program. Indeed, in a recent paper presented to the American Institute for Kitchen Dealers (anderson, 1982), I outlined a 13-step HPE program that if followed likely would increase the chances for survival of small Kitchen and Bath dealerships. Embedded within these 13 steps were considerably more variables to be implemented than discussed in this paper. Nonetheless, those steps outlined in the body of this paper represent the major ingredients (prototype?) of any successful HPE application and, if appropriately adapted to a shipbuilding undertaking, doubtlessly would have a visible and lasting influence in increasing work output. As regards reliable and objective individual measurement, my brief experiences in a single shipyard suggest that numerous obstacles likely will have to be surmounted before such is possible across all of the crafts. Moreover, systematic involvement of leadermen in both the feedback, coaching, and reward phases present numerous challenges at present. Suffice it to say, however, that if such challenges can be met in hotels, food-processing organizations, insurance and real-estate companies, pest-control corporations, a diversity of manufacturing settings, and student work settings, I feel confident that the challenges posed by the shipbuilding industry also can be met with at least equal successes.

And, as regards precise estimates of the effects that can be achieved, an extrapolation from the present data suggests that we

can expect a minimum of a 7% increase in work output simply from development of an behaviorally-relevant measurement system coupled with a statement of its ingredients to employees and supervisors; a minimum of an additional 10% from development and deployment of appropriate feedback programs; and at least another 6-7% (and possibly considerably more) from institution of a relevant reward system. All told, then, it should be possible to achieve and sustain from 20-25% more work output from our front-line operatives as a result of an appropriate application of the HPE approach. And, with the measurement systems and safeguards in place that undergird this approach, there can be no question that convincing proof can be obtained as to whether this claim does or does not achieve fruition. Finally, I can see no reason why some of the other fringes that have been associated with HPE applications also cannot be achieved, including reduced absenteeism and turnover, fewer grievances and conflict, and a generally elevated esprit de corps. All of these effects are traceable to the systematically greater concern and congeniality that leaderman and managers are bound to develop in the process. I know of no other extant work-improvement program that (1) can make such explicit claims, (2) has the means to assess them, (3) the evidence to back them, and (4) the explicit means to achieve them. Please, nonetheless wish me some luck as well just in case!

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# THE FIVE-YEAR NATIONAL SHIPBUILDING PRODUCTIVITY IMPROVEMENT PLAN

Edmund R. Bangs
Executive Director
Institute for Research and Engineering for Automation
and Productivity in Shipbuilding (IREAPS)
IIT Research Institute
Chicago, Illinois

During the past year Mr. Bangs has led the IREAPS organization in supporting the member shipyards. The highlights of the program year have included, two workshops performed at shipyards in CAD/CAM and computer aided estimating, initiation of the CAD/CAM shipyard, the publication of IREAPS and SPC membership directories and the production of another technical symposium with record attendance.

Most notable in the past year has been his chairman role in the development of "The Five-Year National shipbuilding Productivity Improvement Plan".

Mr. Bangs has a diverse background in shipbuilding technology. He was previously employed by the Electric Boat Division of General Dynamics as a nuclear welding engineer. He was the third generation in his family to work in a shipyard. His responsibilities involved the installation of the S5W nuclear reactor piping and pressure vessel systems in submarines which required his direct involvement with all shipyard production groups and problems. He was trained in nondestructive testing, shipbuilding overhaul programs, and nuclear power plant operation. While he has not in the past been directly involved with the REAPS Program, he has been a consultant to the Program. He has been active in manufacturing technology transfer function for the industrial sector and is familiar with many technology areas presently of interest to the shipbuilding industry.

Formerly the Director of the NASA Manufacturing Applications Team at IITRI, he has been involved in the solutions of industry problems with aero-space technology. His most notable shipbuilding related activity in the NASA assignment was the transfer of technology to the marine transport industry. Other application areas have included laser technology, welding systems, CAD/CAM (Air Force-ICAM) and robotics.

## ABSTRACT

The presentation highlights the efforts of 43 management representatives from 15 of the country's major shipyards who have applied themselves in an organized team effort to develop a national shipbuilding productivity improvement plan. The plan identifies the systems and technology required to improve shipyard productivity. Organizations involved included SPC, IREAPS, NAVY, MARAD, MTRB, and the Shipbuilding Council of America.

## PROBLEM

INDUSTRY CURRENTLY IN WORST ECONOMIC SLUMP.

- DECLINE IN COMMERCIAL ORDERS
  - ECONOMY
  - HIGH BUILDING COSTS
  - DWINDLING PRODUCTIVITY

## CHALLENGE

- SUPPORT NAVY EXPANDED SHIP CONSTRUCTION PROGRAM
- REGAIN LEADERSHIP IN WORLD MARKET PLACE,
- IMPROVE PRODUCTIVITY WITH AN ACCELERATED EFFORT

# CORRECTIVE ACTION

**DEVELOP A NATIONAL E-YEAR PRODUCTIVITY IMPROVEMENT PLAN**

- **ORGANIZE STEERING COMMITTEE**
- **CREATE PLAN FRAME WORK**
- **IDENTIFY PROBLEMS THAT IMPEDE PRODUCTIVITY/ INCREASE COSTS**
- **PROPOSE PROBLEM SOLUTIONS - R&D PROGRAM**
- **ANTICIPATED BENEFITS**
- **RECOMMEND FUNDING AND IMPLEMENTATION SYSTEMS**
- **SHIPYARD AND GOVERNMENT AGENCY ENDORSEMENTS**

**SCHEDULED COMPLETION**

**STEERING COMMITTEE**

**TASK GROUP DIAGRAM**

## FIGURE IV-1

# NATIONAL SHIPBUILDING PRODUCTIVITY IMPROVEMENT PLAN INDUSTRY PARTICIPATION

| TASK GROUPS | AVONDALE | BATH IRON | BETHLEHEM | E. B. | INGALLS | LEVINGSTON | | McDERMOTT | NAVSEA | NASSCO | NNS | NORFOLK | PETERSON | TACOMA | TODD | COLLINGWOOD | OTHER* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENGINEERING | ● | | | ● | | | | ● | | ● | ● | | | ● | ● | | |
| MFG. TECHNOLOGY | ● | | | ● | | | | | | ● | ● | | | | ● | ● | |
| BUSINESS ENVIRONMENT | | | ● | | | ● | | | | | | | | | | | ● |
| MATERIAL HANDLING | ● | | | ● | ● | | | | | ● | | ● | | | | | |
| MATERIAL MANAGEMENT | ● | ● | | ● | | | | | | ● | | | | | ● | | |
| HUMAN RESOURCES | | | ● | | | | | | ● | | | | | | | | ● |
| Q. A. | ● | | | ● | | | | | | | ● | | ● | | ● | | |

* OTHER:

- J. J. HENRY
- INT'L. BROTHERHOOD OF BOILERMAKERS
- MARITIME ADMINISTRATION
- MARITIME TRANSPORTATION RESEARCH BOARD
- J. J. McMULLEN
- SHIPBUILDERS COUNCIL OF AMERICA
- UNIVERSITY OF MICHIGAN
- UNIVERSITY OF NOTRE DAME

## PLAN OBJECTIVES

- REDUCE DIRECT LABOR MANHOUR COSTS
- REDUCE CONSTRUCTION SCHEDULE SPANS
- ACCOMPLISH WITHIN 5 YEAR SPAN

## STEERING COMMITTEE AND TASK GROUP MEETING(S)

- IDENTIFY CRITICAL PROBLEM AREAS
- DOCUMENT AND PRIORITIZE PROJECT PROPOSALS
- PROVIDE INDUSTRY CONCURRENCE AND COOPERATION

## STEERING COMMITTEE GOALS

- REVIEW SHIPBUILDING PROCESS FROM PRELIMINARY DESIGN TO DELIVERY
- DELINEATE TASK AREAS:
  - PRODUCTIVITY. PROBLEM DEFINED
  - IDENTIFY PROBLEMS TO BE ADDRESSED
- CREATE TASK GROUPS:
  - ASSIGN MEMBERS AND CHAIRPERSON
  - ASSIGN DUTIES AND RESPONSIBILITIES
- REVIEW AND COMMENT ON PROBLEM AREAS AND PROJECTS IDENTIFIED BY TASK GROUPS
- FINALIZE/APPROVE “THE PLAN”

## TASK GROUP GOALS

- ACCEPTANCE OF PROBLEM DEFINITION FROM STEERING COMMITTEE
- IDENTIFY CRITICAL PROBLEM AREAS IN THEIR TASK; EITHER TECHNICAL, INSTITUTIONAL, OR REGULATORY
- RECEIVE/SEND PROBLEM AREAS (NOT PROJECTS) TO OTHER TASK GROUPS VIA STEERING COMMITTEE
- DEVELOP PROJECTS ADDRESSING PROBLEM AREAS:
  - TASK, SUB-TASK
  - PROBLEM ADDRESSED
  - PROJECT OUTCOME
  - BUDGET (COST)/POSSIBLE FUNDING SOURCES

## TASK GROUP/SPC PANEL INTERACTION

| FUNCTION | S.P.C | S.C. REPRESENTATIVE |
|---|---|---|
| • ENGINEERING | SPC-4 | T. O'DONOHUE |
| • MANUFACTURING TECHNOLOGY | SPC-2 | L. CHIRILLO |
| • MATERIAL HANDLING | SPC-1 | 0. GATLIN |
| • QUALITY ASSURANCE | SPC-2 | E. PETERSEN |
| • HUMAN RESOURCES | SPC-9 | E. BANGS |
| • MATERIAL MANAGEMENT | SPC-6 | R. METAYER |
| • BUSINESS PRACTICES | | J. HILLMANN |

# SHIPBUILDING PROCESS FUNCTION OBJECTIVES

**ENGINEERING ----------- DESIGNS MUST ALWAYS OPTIMIZE PRODUCIBILITY AND MUST NOT CREATE THE RISK OF ERRORS AND INTERFERENCES.**

**MATERIAL MANAGEMENT-------- IMPROVE MATERIAL MANAGEMENT SYSTEMS IN SUPPORT OF STATE-OF-THE-ART TECHNOLOGY IN THE SHIPBUILDING PROCESS, EMPHASIZING THE UNDERLYING NEED FOR STANDARDIZATION.**

**QUALITY ASSURANCE---------- QUALITY MUST BE INTEGRATED INTO EVERY DIMENSION OF THE INDUSTRIAL ORGANIZATIONAL PRACTICE. QUALITY MUST BE REFLECTED IN PRODUCT DESIGN, SPECIFICATION, FABRICATION AND TEST.**

**MANUFACTURING TECHNOLOGY------ ACHIEVE COMPETITIVE OPERATIONS, ORGANIZATIONS AND METHODS WHEREIN TECHNOLOGICAL IMPROVEMENTS OCCUR CONTINUOUSLY REGARDLESS OF SCOPE.**

**MATERIAL HANDLING ---------- DEVELOP AND MAINTAIN A LONG RANGE PLAN THAT WILL OPTIMIZE MATERIAL FLOW TO SUPPORT THE MANUFACTURING OR REPAIR PROCESS IN A TIMELY AND ECONOMICAL FASHION.**

**HUMAN RESOURCES----------- THE CREATION OF AN ENVIRONMENT THAT WILL ATTRACT, TRAIN AND RETAIN QUALIFIED PEOPLE AND ALLOW THEM TO PERFORM AT OPTIMUM POTENTIAL.**

**BUSINESS PRACTICES.---------- ACQUIRE AND PRESERVE AN ECONOMICALLY STABLE BUSINESS CLIMATE FOR SHIPBUILDING THAT WILL ENCOURAGE PRODUCTIVE PRACTICES IN DESIGN, MANAGEMENT AND MANUFACTURING.**

# ENGINEERING TASK GROUP

| | | |
|---|---|---|
| CHAIRMAN: | JAMES WILKINS, GROUP VP ENGINEERING | AVONDALE |
| MEMBERS: | CHARLES STARKENBURG, VICE PRES, | AVONDALE |
| | HERB DOBSON; CHIEF DESIGN & CONST, ENG. | E.B. |
| | DENNIS GARRARD, CHIEF ENG. DIV, | MCDERMOTT |
| | T. H, JACKSON, CHIEF ENG, | TACOMA |
| | PETER BUCKLEY, MGR, ENG. , | TODD |
| | F. B. BARHAM JR., SPC-4 PROGRAM MGR. | NNS |
| | JURGEN KROHAN, MGR., PROD, ENG. | NASSCO |

## ENGINEERING

1. INTEGRATION OF DESIGN/PRODUCTION EFFORT
2. DESIGN FOR PRODUCIBILITY
3. TIMELINESS OF DESIGN DATA
4. CONTROL CHANGES
5. STANDARDIZATION

## ENGINEERING COMMENTARY

1. LACK OF INTERFACE AND INTEGRATION OF OVERALL SHIPBUILDING CONCEPT
2. OVERDESIGNED FEATURES THAT IMPACT MATERIAL AND LABOR COSTS
3. ANTIQUATED SYSTEMS RESTRICT THE TIMELY ISSUE OF DESIGN DATA
4. EXCESSIVE CHANGES REDUCE ENGINEERING PRODUCTIVITY
5. LACK OF STANDARDIZATION IS NEGATIVELY INFLUENCING PRODUCTIVITY

**ENGINEERING FIXES** (20 PROGRAMS)

o DESIGN/PRODUCTION INTEGRATED PROGRAMS RELATED TO:

- THE SHIPBUILDING PROCESS
- SCHEDULING
- COMPUTERIZED INFORMATION FLOW
- IMPROVED DRAWING REVIEW SYSTEM
- DESIGN CHANGE MANUAL
- INDUSTRY WIDE STANDARD FOR DESIGN AND DRAWING PRACTICES
- INDUSTRY WIDE GUIDELINE THAT WILL SPEED UP AND MAKE MORE EFFECTIVE DESIGN DECISION-MAKING
- A STANDARDIZED AND COMPUTERIZED DATA BANK FOR MATERIALS AND EQUIPMENT
- DEVELOPMENT OF COMPUTERIZED DESIGN DATA BANK.

## MATERIALS MANAGEMENT

## TASK GROUP PARTICIPANTS

| | | |
|---|---|---|
| CHAIRMAN: | HERB DOBSONI, CHIEF DES. & CONST. ENGR. | E.B. GROTON |
| MEMBERS: | R. CHEEVALIER, MAT. CONTROL MGR. | E.B. QUONSET POINT |
| | J. FORTIN, PROG MGR. | MARAD/BATH |
| | J. KROHN, MGR, PROD, ENGR. | NASSCO |
| | F. LOGUE, MAT, MGR. | AVONDALE |
| | J. RATCIFF, PROG. OFFICER | TODD, L.A. |

## MATERIALS MANAGEMENT

1. STANDARDIZATION
2. COMPUTERIZATION
3. RECEIPT/INSPECTION
4. PROCUREMENT
5. SPECIFICATIONS

## MATERIALS MANAGEMENT COMMENTARY

1. LACK OF MATERIAL AND DESIGN STANDARDS IMPACTS LEAD TIME LIMITATIONS AND VENDOR COMPLIANCE
2. A COMPUTERIZED SYSTEM THAT IS RESPONSIVE TO CHANGES IN PURCHASING, DESIGN, PRODUCTION, AND MATERIAL DELIVERY
3. INSUFFICIENT ATTENTION GIVEN TO NEEDS FOR SPECIAL PACKAGING
4. EXCESSIVE CHANGES TO MATERIAL AND EQUIPMENT AFTER DESIGN DETAILS ARE COMPLETE
5. PARTS IN MILITARY AND COMMERCIAL APPLICATIONS ARE DUPLICATES BUT ENTAIL DIFFERENT SPECIFICATIONS

## MATERIALS MANAGEMENT FIXES (8 PROGRAMS)

- o DEVELOP SPECIFICATION FOR MATERIALS MANAGEMENT COMPUTERIZED SYSTEM
- o CATALOG OF STANDARD (OFF-THE-SHELF AND NOT-OFF-THE-SHELF) COMMON PARTS
- o DEVELOP STANDARDS AND PROCEDURES FOR MATERIALS RECEIVING FUNCTION
- o DEVELOPMENT OF STANDARD EQUIPMENT MODULES
- o DEVELOP INDUSTRY WIDE PURCHASE ORDER FORMAT

# QUALITY ASSURANCE

## TASK GROUP PARTICIPANTS

| | | |
|---|---|---|
| CHAIRMAN: | T. AVGERINOS, DIR, Q.A. | TODD L.A. |
| MEMBERS: | LOU CHIRILLO, CONSULTANT | TODD L,A. |
| | ORVILLE GAUGER, Q, A, INSPECTOR | PETERSON |
| | GEORGE JOSE, CHIEF, IND. ENG. | E.B. QUINCY |

**QUALITY ASSURANCE**

1. SPECIFICATION AND STANDARDS
2. MANAGEMENT DEDICATION TO QUALITY
3. ADVANCED TECHNOLOGY
4. REGULATORY QUALITY ASSURANCE APPROVAL

**QUALITY ASSURANCE COMMENTARY**

- o INADEQUATE, OUTDATED, INCOMPLETE, AND POORLY DEFINED
- o MANAGEMENT INCONSISTENT
- o EXISTING QUALITY ASSURANCE PROCESSES ARE NOT COST EFFECTIVE AND INHIBIT INTRODUCTION OF ADVANCED TECHNOLOGY
- o TIMELY APPROVAL OF NEW QUALITY ASSURANCE PROCESSES IS LACKING AND DELAYING THE CONSTRUCTION PROCESS

## QUALITY ASSURANCE FIXES (4 PROGRAMS)

- o THE DEVELOPMENT OF A RATIONAL APPLICATION OF STANDARD TESTS AND INSPECTION REQUIREMENTS FOR ALL COMMERCIAL AND GOVERNMENT CONTRACTS FOR NEW CONSTRUCTION AND REPAIR
- o DEVELOP AND INITIATE A MANAGEMENT TRAINING PROGRAM THAT WILL INCREASE MANAGEMENT'S AWARENESS OF QUALITY ASSURANCE IN THE SHIPYARD AND THE COMMITMENT TO QUALITY
- o ESTABLISH AN ADVANCED TECHNOLOGY TASK GROUP TO IDENTIFY SHIPBUILDING INSPECTION PROCESS AREAS THAT ARE COST DRIVERS OR DELAY PRODUCTION AND IDENTIFY ADVANCED TECHNOLOGY WITH POTENTIAL APPLICATION
- o DEVELOP LIST OF ALL PROCESSES AND PROCEDURES THAT HAVE BEEN APPROVED AND CIRCULATE THROUGH INDUSTRY. IT WILL ALSO BE INSTALLED IN DATA BANK

## MANUFACTURING TECHNOLOGY TASK GROUP PARTICIPANTS

| | |
|---|---|
| LOU CHIRILLO, CONSULTANT | TODD L.A. |
| JAMES ACTION, MGR. R&D | TODD L.A. |
| ROBERT DERUSHA, DIR.FAC.& IND.ENG.. | NASSCO |
| JOHN DOUGHERTY | COLLING. TORONTO |
| ORVILLE GAUGER, Q.A. INSPECTOR | PETERSON |
| GEORGE JOSE, CHIEF IND. ENG. | E.B.-QUINCY |

MANUFACTURING TECHNOLOGY FIXES (7 PROGRAMS)

- o TECHNOLOGY IMPLEMENTATION PLAN
  - THE INTERRELATING OF NEW TECHNOLOGIES
  - A PROCEDURE THAT ENABLES THE INDIVIDUAL SHIPYARD TO DETERMINE ITS CURRENT STATUS RELATIVE TO NEW TECHNOLOGY
  - A TIME PHASED APPROACH TO NEW TECHNOLOGY IMPLEMENTATION
- o THE DEFINING OF PLANNING AS A SHIPYARD FUNCTION
- o ZONE ORIENTED WORK PACKAGE
- o PRODUCT WORK BREAKDOWN STRUCTURE FOR SHIP OVERHAULS
- o INTEGRATION OF COST EFFECTIVE WELDING AND RELATIVED PROGRAMS

# MATERIALS HANDLING

## TASK GROUP PARTICPANTS

| | |
|---|---|
| *OLLIE GATLIN, VP-CORPORATE PLANT | AVONDALE |
| THOMAS W. ARCHER, ENV ENGINEER | ELECTRIC BOAT |
| LYN HAUMSCHILT, MANAGER-FACILITIES & IND. ENG, | NASSCO |
| RICHARD A, PRICE, PROJECT MANAGER | AVONDALE |
| L. NORMAM WADDELL, MANAGER-MANU. ENG. | INGALLS |
| GEORGE H. CURTIS III, VP-FACILITIES ENG. | NORFOLK |

MATERIALS HANDLING

1. PROCESS SYSTEMS
2. WORK AREAS
3. UNIT MOVEMENT

## MATERIALS HANDLING COMMENTARY

1. MAJOR DEFICIENCIES EXIST IN HANDLING SYSTEMS WITHIN THE PROCESS SYSTEMS
2. MAJOR COST DRIVERS EXIST IN:
   - ERECTION AND FABRICATION AREAS
   - WET DOCK AND PIERS
   - FLOATING AND GRAVING DOCKS
   - STORAGE AREAS
3. UNIT MOVEMENT CAUSES PROBLEMS IN MATERIAL HANDLING

## MATERIALS HANDLING FIXES (12 PROGRAMS)

- o MOVING PERSONNEL AND LIGHT MATERIAL ONTO A SHIP OR ABOUT A SHIPYARD
- o PIPE STORAGE AND MOVEMENT
- o DEVELOPMENT/APPLICATION OF A MODULAR PALLET TRANSPORT SYSTEM
- o ADVANCED WAREHOUSING CONCEPTS
- o THE APPLICATION OF COMPUTER TECHNOLOGY TO:
  - THE MONITORING OF FUEL USAGE
  - SHIPYARD FACILITY LAYOUTS
- o THE DEVELOPMENT OF A UNIVERSAL TRANSPORTER

# HUMAnN RESOURCES
# T A S K G R O U P

| | |
|---|---|
| FRANK J. LONG, GEN. MGR., HUMAN RES. | BETH, STEEL |
| D. ANDERSON, DEPT, PSYCHOLOGY | NOTRE DAME- |
| H. BUNCH, SPC-9 CHAIRMAN | UNIV. MICH. |
| M. GAFFNEY, PROG, MGR. | MTRB |
| J. HARTIGAN, DIR, SHIPYARD TRAIN, | NAVSEA |

## HUMAN RESOURCES

1. EDUCATION
2. ACQUISITION AND RETENTION
3. COMPENSATION SYSTEMS
4. BEHAVIORAL PRACTICES AND TECHNIQUES
5. WORK FORCE DATA BASE

## HUMAN RESOURCES COMMENTARY

1. INSUFFICIENT AMOUNT OF PROPERLY TRAINED PROFESSIONAL, SUPERVISORY, AND TRADES PERSONNEL
2. HIGH ATTRITION IN SKILLED TRADES
3. SYSTEMS DO NOT FOSTER SKILL ACQUISITION AND PRODUCTIVITY IMPROVEMENT
4. INSUFFICIENT APPLICATION OF BEHAVIOR AND MOTIVATIONAL TECHNIQUES
5. THERE IS A NEED FOR A CONSTANTLY UPDATED WORK FORCE DATA BASE

## HUMAN RESOURCES FIXES (12 PROGRAMS)

- o EMPLOYEE MOTIVATION
  - ANALYSIS OF SELECTED HUMAN RESOURCE ISSUES THAT ARE CONSIDERED COST DRIVERS AND IMPACT PRODUCTIVITY
  - DEVELOPMENT OF "ZERO" VOLUNTARY AND INVOLUNTARY TERMINATION PROGRAM
  - DEVELOPMENT OF SKILLED TRADES COMPENSATION SYSTEMS TO REFLECT INDIVIDUAL AND GROUP PRODUCTIVITY ACHIEVEMENTS
  - DEVELOP SYSTEM TO ESTABLISH AN EQUITABLE RELATIONSHIP BETWEEN SKILLED TRADES AND MANAGEMENT COMPENSATION LEVELS
- o PERSONNEL POLICIES AND PROCEDURES
  - "ZERO" ACCIDENT PROGRAMS
  - REDUCTION OF ATTRITION RATES OF SKILLED WORKERS
  - PROGRAMS TO ATTRACT NEW TRADES AND PROFESSIONAL EMPLOYEES
- o TRAINING AND DEVELOPMENT
  - EXPANDED USE OF IN-HOUSE TRAINING PROGRAMS

## BUSINESS ENVIRONMENT TASK GROUP PARTICIPANTS

CHAIRMAN: FRED HILLMANN. DIR. BUS. DEV. — LEVINGSTON

MEMBERS:
STUART S. ADAMSON: V.P. — SHIP. COUNCIL AM,
HERBERT FREINBERG, GEN. MGR, OP. & FAC.* — BETH STEEL
JOHN M, HOTALING, MGR. SHIP. ANALYSIS — MARITIME ADM.
GORDON PLANCICH, SUPV., ENG, COMPUTER SERV. — J.J. HENRY
RICHARD W, THORPE, V.P. CORP. PLAN; & DEV, — J. J. MCMULLEN

## BUSINESS ENVIRONMENT

1. CONTRACTS AND SPECIFICATIONS
2. REGULATORY BODIES
3. R&D PRODUCT DEVELOPMENT
4. BUSINESS PLANNING

## BUSINESS ENVIRONMENT COMMENTARY

1. CONTRACTS WITH INEFFICIENT LANGUAGE, PRACTICES AND REQUIREMENTS
2. IMPOSE OUTDATED AND REDUNDANT REQUIREMENTS
3. NO R&D ACTIVITY DUE TO LACK OF INCENTIVES

## BUSINESS ENVIRONMENT FIXES (7 PROGRAMS)

- o IDENTIFYING ALTERNATIVE ACTION THAT GOVERNMENT CAN TAKE TO ASSIST THE INDUSTRY IN STRENGTHENING ITS WORLD MARKET POSITION
- o ANALYSIS OF WORKLOAD VARIABILITY ON SHIPBUILDING PRODUCTIVITY
- o THE PROPOSAL OF ALTERNATE SYSTEMS TO IMPROVE THE NAVAL SHIP PROCUREMENT PROCEDURES
- o ANALYSIS OF EXISTING NAVAL SPECIFICATIONS AND IDENTIFICATION OF REQUIRED REVISIONS
- o THE DEFINITION AND REQUEST FOR REVISION OF REGULATORY REQUIREMENTS THAT NEGATIVELY IMPACT COST AND PRODUCTIVITY

# IMPLEMENTATION

- IMMEDIATE SOLUTION TO SELECTED PRODUCTIVITY PROBLEMS
- REFERENCE FOR ESTABLISHING ADVANCED STRATIEGIC PLANS (GOVERNMENT AGENCY
- REFERENCE FOR SHIPYARD PLAN FORMULATIONS AS IT RELATES TO SHIPBUILDING FUNCTIONS
- MEDIUM AND LONG RANGE PLANNING GUIDE AT SHIPYARD LEVEL
- GENERAL EDUCATION GUIDE TO PLAN DEVELOPMENT AND SHIPYARD FUNCTIONS
- PLANNING APPLICATIONS FOR SUPPLIERS AND CONTRACTORS

# PROJECT FUNDING

**FUNDING SOURCES**

- PRIVATE SHIPYARDS
- SUPPLIERS AND SUBCONTRACTORS
- NAVAL ARCHITECTURE/MARINE ENGINEERING AND OTHER CONSULTING FIRMS
- U. S. NAVY
  - -NATIONAL SHIPBUILDING RESEARCH PROGRAM
  - -PROCUREMENT CONTRACTS
  - -TECH MOD/MANUFACTURING TECHNOLOGY/ SHIPBUILDING TECHNOLOGY
  - -INDEPENDENT RESEARCH AND DEVELOPMENT
- MARITIME ADMINISTRATION
  - -NATIONAL SHIPBUILDING RESEARCH PROGRAM
- U. S. COAST GUARD
  - -PROCUREMENT CONTRACTS

# PLAN BENEFITS

**CUSTOMER**

PRIMARY – REDUCED COST OF SHIPS
- REDUCED CONSTRUCTION SCHEDULES
- SHIPS OF HIGHER QUALITY
- DATA ESSENTIAL TO STRATEGIC ADVANCED PLANNING

SECONDARY – PROVIDES INDUSTRY WIDE "VOICE"
- SMOOTHER CUSTOMER/SELLER NEGOTIATIONS
- ACCELERATE PROJECT FUNDING CYCLE
- STREAMLINE THE CONTRACTING PROCESS

**INDUSTRY**

PRIMARY INCREASED PRODUCTIVITY
- REDUCED COSTS
- ESTABLISH MARKET COMPETITIVE POSITION INCREASED SALES
- STRENGTHEN AND STABILIZE FINANCIAL POSITION
- INCREASED R&D BUDGET

SECONDARY IMPROVED WORKING CONDITIONS
- REDUCED PERSONNEL TURNOVER

**NAT1ONAL**

PRIMARY - SAVINGS TO THE TAXPAYER
- BETTER USE OF TAXPAYER DOLLARS
- REDUCED UNEMPLOYMENT
- STRONGER AND QUICKER RESPONSE TO THE NATION'S DEFENSE

SECONDARY - STRENGTHENING AND PROVIDING A FIRM INDUSTRIAL BASE FOR U.S. SHIPBUILDING INDUSTRY
- CONTRIBUTES TO HEALTHIER ECONOMY
- STIMULATES AND ATTRACTS NEW PERSONNEL